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Secondary Science

A Teaching Resource

NOVA SCOTIA
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SECONDARY SCIENCE
A TEACHING RESOURCE

Secondary Science: A Teaching Resource

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INTRODUCTION

Secondary science curricula are changing in the Atlantic provinces. Although much of the content will be familiar, students will be expected to apply their knowledge and skills in progressively richer contexts. This requires a learning environment that differs from that of the traditional science classroom. The *Secondary Science Teachers' Handbook* was produced to assist teachers as they bridge the gap between traditional and new approaches to teaching science and is meant to support the development of alternative perspectives and strategies.

This handbook also was developed to assist secondary science teachers in implementing new methodologies. These methodologies will help students attain scientific literacy and will increasingly be found in curriculum documents relating to science education in Nova Scotia.

Teachers can read this document at their leisure or scan specific chapters of interest. Chapters have been organized by theme or purpose. Also, to allow for future chapter revisions or additions, chapters within each section have been paginated independently. (For example, chapter 1, page 3, is numbered 1.3; chapter 2, page 7, is numbered 2.7, and so on.)

The strategies, skills, and perspectives described in this handbook represent considerable change for many teachers. Teachers are therefore encouraged to

- start small—try something that feels comfortable and build competence with time
- network with others
- take advantage of professional development opportunities

CHAPTER 1: THE CHANGING LANDSCAPE OF SCIENCE EDUCATION

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Science education is in a process of change driven by conversations and deliberations around the role that science education should play in the development of our young people. As a result of these discussions and in response to the perceived needs of students as they prepare to take their place in a rapidly changing society, the goals of science education are broader than ever before. A comparison of the purposes of science education in the 1960s with those of today might produce the following summary:

Descriptor	1960s	Today
End Product	Production of scientists and engineers.	Production of a scientifically literate population.
Knowledge	Acceptance or verification of decontextualized knowledge produced by others.	Construction of an individual's scientific world view, reflecting societal and environmental contexts.
Thinking and Skills	Linear thinking, emphasizing *the scientific method.*	Creative thinking, involving science inquiry, problem solving, and decision making (often interdisciplinary).

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them. To do this, students require diverse learning experiences and many opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the relationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their future (Council of Ministers of Education, Canada, 1997).

For many teachers, this focus on scientific literacy is a significant change. So to effect this change, science education in Nova Scotia must also change and evolve. Major areas affected are

- instruction
- student learning
- assessment and evaluation
- classroom structure

Changes in Instruction

As a result of this change, science teachers will take on many roles in the classroom, becoming more often facilitators of learning rather than deliverers of information.

Science teachers will take on many roles in the classroom, becoming more often facilitators of learning rather than deliverers of information.

Teachers' roles also will continually evolve as teachers meet the challenges of changing curricula. In this process, teachers will continue to apply their most effective teaching strategies; however, in many cases, other strategies will also be incorporated into classroom practice.

For students to function as future citizens in a society influenced by science, technology, the environment, and the economy, they will need to be scientifically literate. Regardless of career choices, students must know how to think independently and how to make informed decisions that consider multiple perspectives.

Teachers can foster intellectual autonomy and independence in their students by taking on the role of facilitator, encouraging their students to become *active learners*. Without that active participation, development of student's communication, problem-solving, and decision-making skills will be hindered.

In response to the broader purposes of science education, teachers have begun to make their classrooms more learner centred. Teachers still lecture, demonstrate labs, and direct discussions, but they are more selective about how they use class time so that students are active the majority of the time. In this sense, teachers are beginning to practise *strategic teaching.*

> … strategic teachers have a dual agenda as they consider how to relate content and instruction to learning. They must balance a focus on content priorities with strategic instruction not only as they plan sequences of instruction, but also during the act of teaching in the classroom. When strategic teachers identify content goals, they also consider the strategies that students need to learn the content well (Jones, Palincsar, Ogle, and Carr, 1987, 50).

Teachers will use a variety of strategies as they encourage students to think more about science and about how they learn …

Teachers will use a variety of strategies as they encourage students to think more about science and about how they learn—strategies such as Compare and Contrast think sheets or writing-to-learn activities. These and other practical strategies are described in this handbook. This does not mean that a particular strategy, such as co-operative learning, will be used all the time. Rather, teachers need to expand the repertoire of teaching tools to actively engage students in their own learning process. Teachers have a vast array of knowledge and skills for science teaching at their disposal. The challenge is to put that repertoire to use in new ways.

Changes in Student Learning

In classrooms where teachers are facilitators of learning rather than dispensers of scientific knowledge, students will develop stronger interactive and collaborative skills with their peers. They will also develop an understanding of how they learn.

As we address these new goals of science education, we expect that some classroom activities will resemble present practice. Students will still work in small groups, handle laboratory equipment, and use charts, graphs, and diagrams to organize data. Student-teacher interactions also will continue to include question-and-answer patterns and large group discussions. On the other hand, some notable changes will likely occur.

Visitors to Nova Scotia science classrooms will begin to notice greater student involvement with the content material. Students will have more opportunity to pose and answer their own questions. They will be doing more reflective writing and interactive reading, and more to organize concepts in maps or frames, and connect new ideas with prior knowledge. Some of these activities will involve paper and pen, while others will need audiovisual tools to access and process information. Computers, videodiscs, and films are among the tools that students will use to gather, process, and communicate information.

... the most important change will be the quality and frequency of student interactions with one another.

However, the most important change in science education will be the quality and frequency of student interactions with one another. This change reflects the kind of collaboration and intellectual independence required to deal with scientific and technological questions in the twenty-first century. This focus on meaningful interactions among students is a key element in science education today.

Changes in Assessment and Evaluation

Teaching, assessing, and evaluating should be closely linked. Assessment and evaluation should occur on an ongoing basis as integral parts of the learning process. Students who received frequent, meaningful feedback have the opportunity to recognize their own progress and thus may come to value their own learning as well as that of their peers. Teachers can use a variety of multifaceted assessment tools and evaluation criteria to

- demonstrate what students have learned and are able to do
- assess and evaluate both process and product
- describe where the student is on the continuum of learning
- celebrate students' unique abilities and achievements
- assess and evaluate collaborative, oral, interactive, and higher level thinking skills

Furthermore, teachers will collaborate with students in the assessment and evaluation processes so that students know clearly what is expected of them.

In addition to lab reports, quizzes, and tests, teachers will use research reports, oral and multimedia presentations, performance assessments of various skills, teacher observations and anecdotes, interviews, journals, and portfolios. These assessment strategies not only will tell students what is important, they also will reflect the changing goals of science education.

A combination of self-, peer, and teacher assessments and evaluations will shift the emphasis toward a shared responsibility for learning.

Changes in Classroom Structure

Classrooms will need to be flexible spaces that support both traditional teaching methods and those that are more collaborative and innovative.

Modern educational philosophy is more learner centred and so requires classrooms that support increased student activity. The physical setting must foster instructional variety, both by its design and by its technological supports. At times, there will be a need for traditional lectures or lab activities. At other times, teachers will need to use a variety of instructional strategies that encourage interactive learning, including

- co-operative learning
- research skill development
- differentiating instruction
- application of various technologies

Activities in the learner-centred classroom will include students completing tasks in small teams, interacting with various technologies and multimedia at work stations, or working one-on-one with the teacher.

To accommodate these different modes of learning, the science classroom must be made more flexible.

To accommodate these different modes of teaching and learning, the science classroom must be made more flexible. The physical space should allow for whole-class, small-group, and/or individual learning. Learners need not always perform the same tasks to achieve the same outcomes, and just as there are multiple pathways to achieve outcomes, there are also multiple ways for students to demonstrate what they know and can do.

Summary

Science education in Nova Scotia schools is changing to reflect a broader purpose, focusing on science literacy, research skills, interdisciplinary thinking, decision making, collaboration, and communication. This evolution directly affects students' roles, teachers' roles, assessment, and the physical classroom in these ways:

- Students will be engaged in their learning as they are problem solving, considering societal concerns, and developing higher-level thinking skills.

- Teachers' roles will change as they become facilitators, encouraging their students to become active learners.
- Assessment will be multifaceted, acknowledging students' learning styles and appropriate modes of demonstrating their learning.
- Classrooms will become flexible spaces that support a variety of traditional and interactive activities.

References

American Association for the Advancement of Science. *Benchmarks for Science Literacy.* Ed. J. Rutherford. Toronto, ON: Oxford University Press, 1993.

American Association for the Advancement of Science. *Science for All Americans.* Ed. J. Rutherford and A. Ahiglen. Toronto, ON: Oxford University Press, 1990.

Atlantic Provinces Education Foundation. *Foundation for the Atlantic Canada Science Curriculum.* Halifax, NS: APEF, 1998.

Council of Ministers of Education, Canada. *Common Framework of Science Learning Outcomes.* Toronto, ON: CMEC, 1997.

International Association for the Evaluation of Educational Achievement (IEA). *Curriculum Frameworks for Mathematics and Science: Third International Mathematics and Science Study* (TIMSS). Monograph No. 1. Ed. D. Robitaille. Vancouver, BC: Pacific Educational Press, 1993.

Jones, B., A. Palincsar, D. Ogle, and E. Carr. *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas.* Alexandria, VA: Association for Supervision and Curriculum, 1987.

National Research Council. *National Science Education Standards.* Ed. R.D. Klausner. Washington, DC: National Academy Press, 1994.

National Science Teachers' Association. *Science Technology and Society.* Ed. Rodger Bybee. Arlington, VA: National Science Teachers' Association, 1987.

Science Council of Canada. *Science for Every Student,* Ottawa, ON: Minister of Supply and Services, 1984.

Science Council of Canada. *Science Education in Canadian Schools,* Ottawa, ON: Minister of Supply and Services, 1984.

Yager, R. "Viewpoint: What We Did Not Learn from the 60's About Science Curriculum Reform." *Journal of Research in Science Teaching*, 29.5 (1992).

CHAPTER 2: TAPPING INTO PRIOR KNOWLEDGE

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Students construct new learning structures on a foundation of prior knowledge (Driver, 1988).

In science education today, we generally accept a constructivist model of learning. Constructivist learning theory and the importance of prior knowledge in science education are summarized by the American Association for the Advancement of Science (1989) as follows:

> People have to construct their own meaning regardless of how clearly teachers or books tell them things. Mostly, a person does this by connecting new information and concepts to what he or she already believes. Concepts—the essential units of human thought—that do not have multiple links with how a student thinks about the world are not likely to be remembered or useful. Or, if they do remain in memory, they will be tucked away in a drawer, labelled, say "biology course, 1995," and will not be available to affect thoughts about any other aspect of the world. Concepts are learned best when they are encountered in a variety of contexts and are expressed in a variety of ways, for that ensures that there are more opportunities for them to become imbedded in a students' knowledge system.
>
> But effective learning often requires more than just making multiple connections of old ideas to new ones; it sometimes requires that people restructure their thinking radically. That is, to incorporate some new idea, learners must change the connections among the things that they already know, or even discard some long-held beliefs about the world. The alternatives to the necessary restructuring are to distort the new information to fit old ideas or to reject the new information entirely. Students come to school with their own ideas, some correct and some not, about almost every topic they are likely to encounter. If their intuition and misconceptions are ignored or dismissed out of hand, their original beliefs are likely to win out in the long run, even though they may give the test answers that the teachers want. Mere contradiction is not sufficient; students must be encouraged to develop new views by seeing how such views help them make better sense of the world (p. 145–6).

This chapter defines prior knowledge, explains the importance of tapping into it, and offers strategies for doing so.

The Three Aspects of Prior Knowledge

Before introducing new material, teachers can help students consider three aspects of their prior knowledge related to a topic. These include

- existing concepts
- the vocabulary that they use to represent these concepts
- the ways in which these concepts relate to each other and to other topics

What concepts and understanding does a student have about this topic?

Students often come to science class with misconceptions and alternative theories that may ultimately shape what they will believe and come to learn (Cook, 1993). Teachers and students must be aware of students' existing ideas and explanations so that they can address them and take them into consideration in the classroom.

What vocabulary does the student have related to this topic? Does this vocabulary reflect the publicly accepted view of these terms?

Teachers can either assist students in accessing the vocabulary that they already know or preteach vocabulary so that new material will be better understood. Teachers should be careful, however, not to equate student's use of a vocabulary term in an appropriate context with conceptual understanding.

Can the student recognize how the topic or material is organized or presented?

Teachers can help students recognize new organizational styles and how they correlate to those with which they are familiar. For example, students may be familiar with a particular laboratory format or textbook design that differs from that being used in your classroom and therefore be lost when the "materials" section changes to the "apparatus" section in a laboratory report.

Implementing Prior Knowledge Strategies

All students can develop skills to activate and link their prior knowledge to new information by learning to sift through, organize, and relate new information to what they already know. These skills are often referred to as core skills (Jones, Palincsar, Ogle, and Carr, 1987) and are particularly important for problem solving.

When a new problem is presented, students should look for similarities to problems previously encountered. If the topic is familiar, if key words stand out, or if the pattern is recognized, students activate a "likely set of procedures for solving the problem" and estimate a "likely outcome" (Jones et al., 1987, 8).

With specific strategies, students can develop the skills required for activating prior knowledge.

With specific strategies, students can develop the skills required for activating prior knowledge. Teachers can first choose appropriate strategies by

- looking at how they would normally introduce a topic
- determining which prior knowledge strategy would best blend with that approach to strengthen it

Teachers can help students become familiar with the prior knowledge strategy by

- modelling the steps of the strategy
- working with one strategy until students are comfortable with it
- practising a strategy with a variety of topics so that students will use the strategy without prompting

While students work with a particular strategy, the teacher then would

- circulate, helping those who are slow to begin
- give a few key words or hints
- do some one-on-one teaching

Prior knowledge will be tapped into and extended if students have a chance to share and talk about what they have produced.

Prior knowledge will be tapped into and extended if students have a chance to share and talk about what they have produced. Many of the prior knowledge strategies should be incorporated in the Listen—Think—Pair—Share approach.

Listen—Think—Pair—Share (LTPS)

1. The teacher places students in teams of two or three (if necessary), pairing or grouping students in advance to save time.
2. Students *listen* to a lecture, watch a demonstration, try a lab activity, or are exposed to content in some manner.
3. The teacher gives each student a specific task to do that requires *thinking* about the content, such as solving a problem, writing in a log, completing a think sheet, answering a question, and so on. Students do not talk during think time so everyone has a chance to work uninterrupted. Wait time is built in.
4. Students *pair* up with preassigned partners and share what they have done. This would involve explaining how they got a particular solution. If one team finished before another an alternate activity should be available.
5. Students *share* their results. The teacher calls upon certain students to give answers and outline the problem-solving steps.

   It is also important for teachers to help students categorize their prior knowledge. Information is remembered best when grouped using clustering strategies such as an outline or a Concept Map.

   For example, students could be asked to predict the change in a given ecosystem, based on a change in a particular abiotic factor, the introduction of a new species, or the extinction of an existing species.

   Students could generate predictions and describe the resulting changes as well as the reasons for those changes.

Listen—Think—Pair—Share: From F.T. Lyman and J McTighe, "Mind Tools for Matters of the Mind." In A.L. Costa, J. Bellanca, and R. Fogarty, eds., *If Minds Matter: A Foreword to the Future*, Vol. II. ©1992 by IRI/Skylight Training and Publishing, Inc., Palatine, IL. Used with permission.

Strategies

The following strategies are outlined in detail in this chapter:

1. **Concept Map**
2. **KWL (Know—Want to Know—Learned)**
   KWL Plus
   Knowledge Chart
3. **Listen—Draw—Pair—Share**
4. **PReP (PreReading Plan)**

1. Concept Map

A concept map is intended to help students identify

- key vocabulary for a topic
- relationships between terms within a topic

Procedure

Initially, the teacher can demonstrate this procedure. Once students understand the steps taken in building a Concept Map, they can independently:

1. list the lesson's key vocabulary on small pieces of paper
2. arrange the words to show relationships or logical connections between them
3. draw lines and write connecting phrases between words
4. suggest additional vocabulary and better or different connections

The map that results will show major concepts and relationships (refer to Figure 2.1).

Suggestions

- Help students begin concept mapping independently or in small groups by offering some basic terms with which everyone is familiar.
- Remind students that no two maps are likely to look the same. The intent is to build the map and be able to explain and justify the groupings and connections.
- Refer to *Chapter 4: Developing Scientific Concepts Using Graphic Displays*, for additional information on creating Concept Maps.

Example

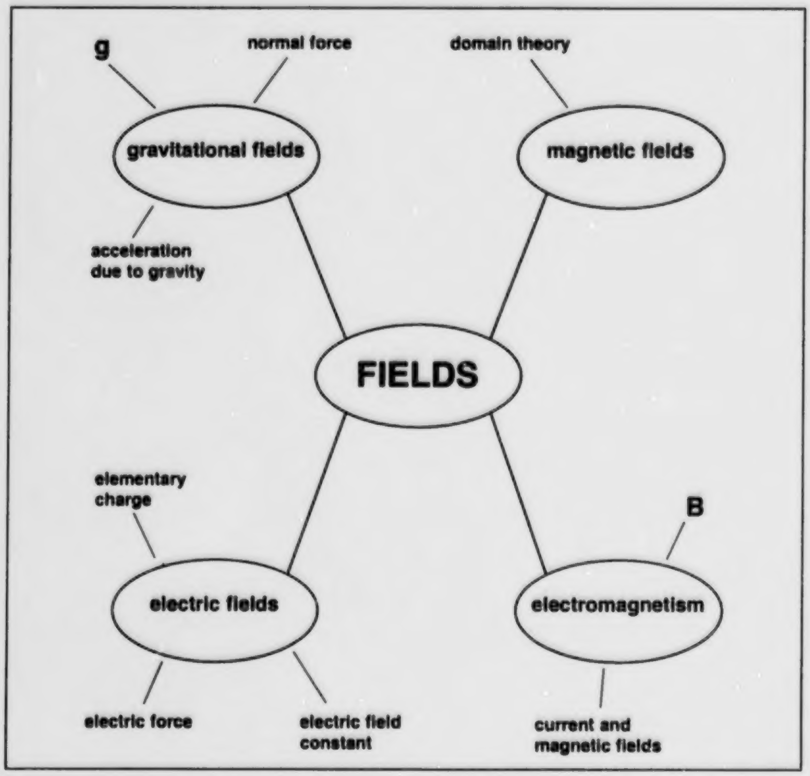


Figure 2.1: Example of a concept map for a fields unit in physics.

2. KWL (Know—Want to Know—Learned)
KWL Plus
Knowledge Chart

The **KWL** strategy asks students to identify what they

Know—what they already know

Want to know—what they want to know

Learned—what they learned in the lesson or unit

The results for each phase are recorded on a three-column chart (refer to Figure 2.2).

Procedure

The *Know* Phase

1. The teacher introduces the topic (that is, tells students what it is, shows a short video, reads a passage, does a lab demonstration).
2. The class brainstorms about the topic.
3. Students individually write down all they know about the topic (trying to expand on what was said) in the K column.
4. Students look for natural clusters of terms and write down suggested categories at the bottom of the K column.

NOTE: The list of terms in that column can alert teachers to strengths or weaknesses in vocabulary.

The *Want-to-Know* Phase

5. Students share lists of terms and categories with partners and then with the rest of the class.
6. Students can build a class Concept Map in the W column. This shows what some students know and helps others identify what they need to learn.
7. Students list questions below the map or list of terms. These questions could be a result of discussing the material or from building their list in the K column.

The *Learned* Phase

8. The teacher proceeds with the lesson or unit.
9. Students add questions to the W list.
10. Students begin to write down answers to their questions in the L column.

11. The teacher provides a time out for students to recheck their questions and also monitors if questions are being answered.
12. Students share their answers with the class, record them on wall charts, or write about them in journals. The more answers discussed, the better the learning.

KWL (Know—Want to Know—Learned) is one of the most widely recognized and frequently used prior knowledge strategies. Many variations of it exist, including KWL Plus and the Knowledge Chart. Originally used as a pre-reading strategy, its application has expanded, and it is frequently used as an introduction to a single lesson or an entire unit.

The **KWL-Plus** strategy adds a step 13 here.

13. At the end of the lesson or unit, each student builds a new concept map that incorporates both what they "knew"—the original information and then what they've "learned"—the new material covered after they reevaluated the categories. Students also write a summary of the material. This concept map provides a valuable review sheet and summary for students.

The **Knowledge Chart** is a simple variation of KWL. The W column becomes an N column, rephrased as "what do you *Need* to know."

Students write down what they'll need to know to succeed in the lesson or unit. Students can then check at the end of a strategy if they learned what they needed to know (refer to Figure 2.3).

For blank copies of the KWL-Plus and Knowledge Chart, refer to Attachments 2.1 and 2.2 at the end of this chapter.

Examples

KWL Strategy

Course Physical Sciences　　　　Topic Solutions

Know	Want to Know	Learned
– stuff mixed in water	How can a solid dissolve in a solid?	– types of solutions
– used in labs	Is dissolving a chemical reaction?	– how to mix solutions faster
– filter it	What is an alloy?	– solution concentrations
– salt in water	What is hard water?	– why water is special
– solute	How strong are the chemicals we use in labs?	– electrolytes
– solvent		– solutions versus suspensions
– stir it to mix faster		– 12 kt vs 18 kt gold
– sand in water		– water softeners
– sugar in water		

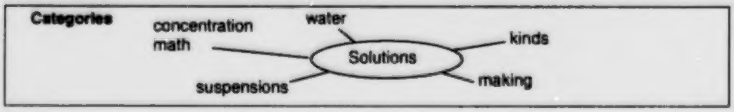


Figure 2.2: KWL-Plus chart on solutions for a physical science unit

KWL Plus: Jones, B., A. Palincsar, D. Ogle, and E. Carr. *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas.* Alexandria, VA: Association for Supervision and Curriculum, 1987.

Two examples of Knowledge Charts are presented in Figures 2.3 and 2.4. These students not only listed what they knew, they drew it. The L column was completed later in the unit.

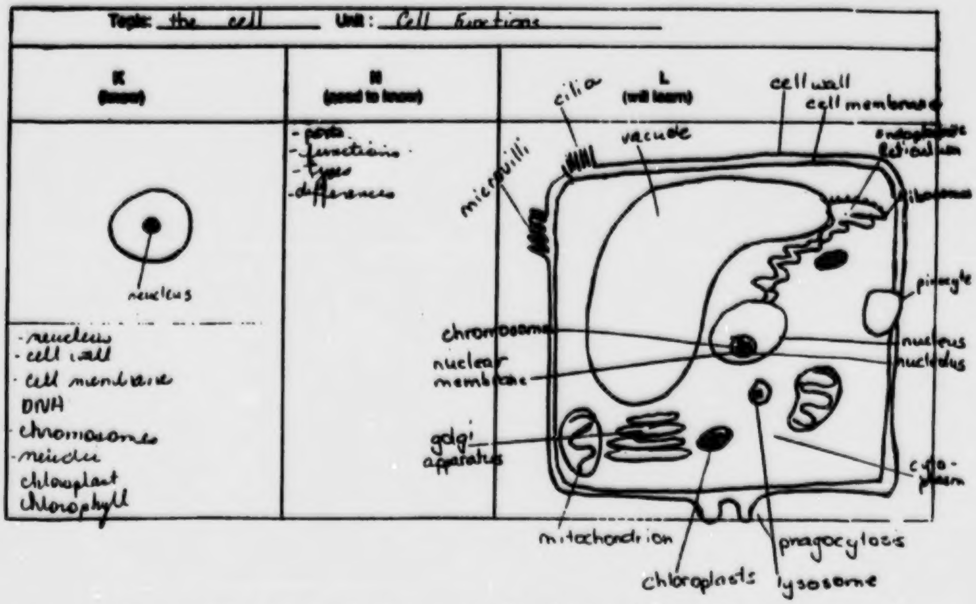


Figure 2.3: A student's Knowledge Chart for the cell.

In this example, the student's prior knowledge of the cell did not extend beyond the "fried egg" model. Four main categories are listed in the N column. A more elaborate cell model is drawn in the L column.

Biology

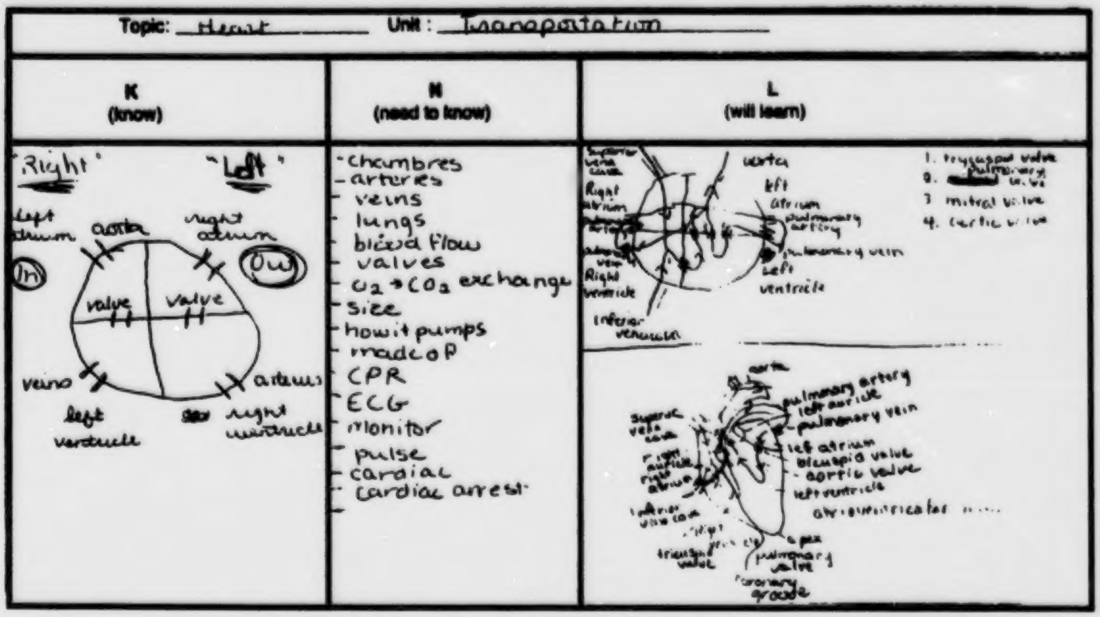


Figure 2.4: A student's Knowledge Chart for the heart and transportation in biology.

In Figure 2.4, the student remembered that the heart has chambers, valves, and vessels. Right and left were reversed and later corrected. Major concepts in the transportation unit are listed in the N column. When the student was part way through the unit, she drew the heart again at the top of the L column. When the unit was completed, she drew a better version below her original.

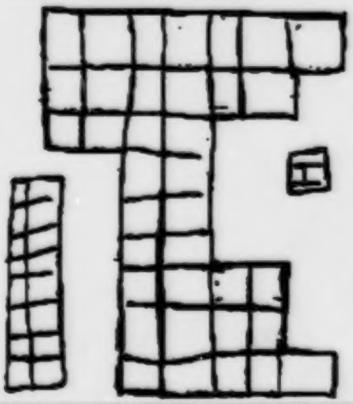
Other versions of knowledge charts are presented in Figures 2.5 and 2.6.

Knowledge Chart

Course Chem   Unit Periodic Table

What do you know about the Periodic Table **?**

Know now (draw):



Know now (list):

- atomic number
- atomic mass
- symbols (names)
- atoms, elements, protons, neutrons, ions, isotopes
- chemistry
- chlorine, sulfur, silicone, mendilenium, erbium, titanium, magnesium, helium, sodium
- noble gases

Hydrogen
Magnesium
Lithium
Fluorine
Gold
Neon
Uranium
Aluminum
Oxygen
Zinc
Krypton
Boron
Bronian

Need to know:

* Families
  → halogens, alkaline earth metals, noble gases
* Sizes
  → atoms, ions
* Elements
* Properties
  → reactivity, radioactive, oxidation #s, ionization energy, electronegativity, density, melting and boiling pts.
* Shape
  → box

List what you have learned:

Chemical formulas, Trends, States, covalent, molecular, noble gases, bonding, elements, alkaline Earth, binary, ternary, alkali, transition zone, chalcogens, stable protons, halogens, electrons, neutrons, metals, non-metals, ionization energy, electronegativity, atomic and ionic nuclei, naming formulas, subscript, reactive symbols, polyatomic, monatomic,

readings—matter, atoms, periodic table, bonding

Final concept map or drawing:

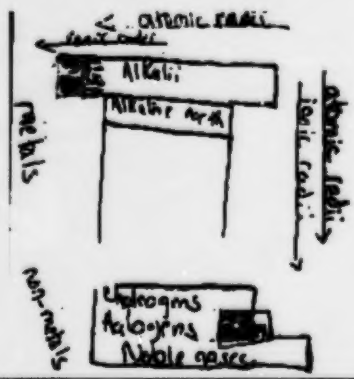


Figure 2.5: A student's Knowledge Chart for the periodic table

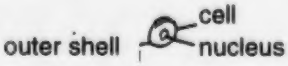
Knowledge Chart: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

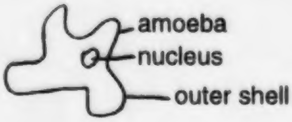
Knowledge Chart

Course Biology   Unit Cells

What do you know about Cells?

Know now (draw):





Know now (list):

- tissue
- organ
- blood cells (white, red) erythrocyte
- prison
- nucleus ?
- living
- amoeba
- organelles
- atoms
- Robert Hook
- cytoplasm
- extracellular fluid ' interstitial
- cell membrane
- molecules
- multicellular
- unicellular
- vacuoles

Need to know:

- Animal Cells
- Plant Cells

Cytoskeleton

Boundaries

All

Energy Transformers

Storage and Assembly

Control

List what you have learned:

- Osmosis
- Active/Passive Transport
- Diffusion
- Hypertonic
- Hypotonic
- Isotonic
- Pinocytosis
- Phagocytosis

Final concept map or drawing:

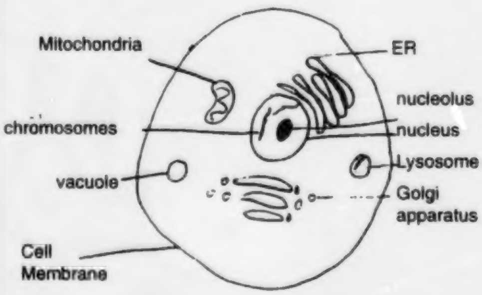


Figure 2.6: A student's Knowledge Chart for cells.

3. Listen—Draw—Pair—Share

This strategy requires that students draw what they know about a topic both before and after some instruction. The drawings they produce show what they perceive to be the main ideas.

Procedure

The steps of the Listen—Draw—Pair—Share strategy are as follows:

1. Students create and label a drawing that illustrates what they know about the topic.
2. Students share and compare their drawing with at least one other student. They must explain the labelling.
3. Students then share what they know about the topic in a class discussion. The teacher may list the information or put it on a Concept Map.
4. The teacher presents new information either with an assigned reading, lecture, or film or using some other strategy.
5. Students alter or adapt their drawings or create new drawings.
6. Students share their before and after drawings with other students and explain the changes or differences and the reasons for them.

Variations

a. Students *listen* to instructions and brainstorm. They then *think* independently about the topic and create and label a drawing.
b. Students share work with a partner. This is much less threatening than having to share drawings or lists with the whole class. Voluntary sharing with the class can follow.

Suggestions

The Listen—Draw—Pair—Share strategy lends itself to the drawing of biological specimens, organs, or copies of electron micrographs. Teachers and students can develop performance assessments that distinguish the key features in drawings, such as

- Detail—appropriate/accurate (e.g., colour pattern, texture, and/or other physical characteristics)
- Representation—use of multiple views

Listen—Draw—Pair—Share: Adapted from McConnell, Suzanne. "Talking Drawings: A Strategy for Assisting Learners." *Journal of Reading* 36.4 (Dec. 1992/Jan. 1993). Used by permission of International Reading Association.

- Scale—consistent/marked clearly/metric
- Labels—accurate
- Presentation—neat/effective use of paper size or computer screen

Drawings created after instruction can be self-evaluated or evaluated by peers or teachers.

Example

As shown in Figures 2.7 and 2.8, the students were asked to draw about population explosion both before and after they had read a related article about it.

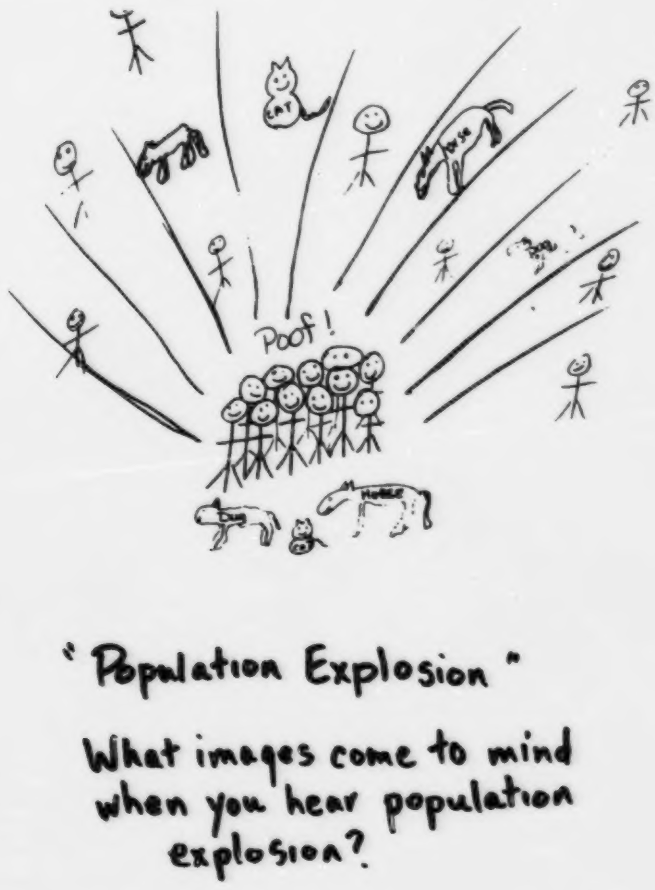


Figure 2.7: The "before" drawing of a population explosion.

In the "before" picture, the student showed that people and animals appear to multiply at a rapid rate.

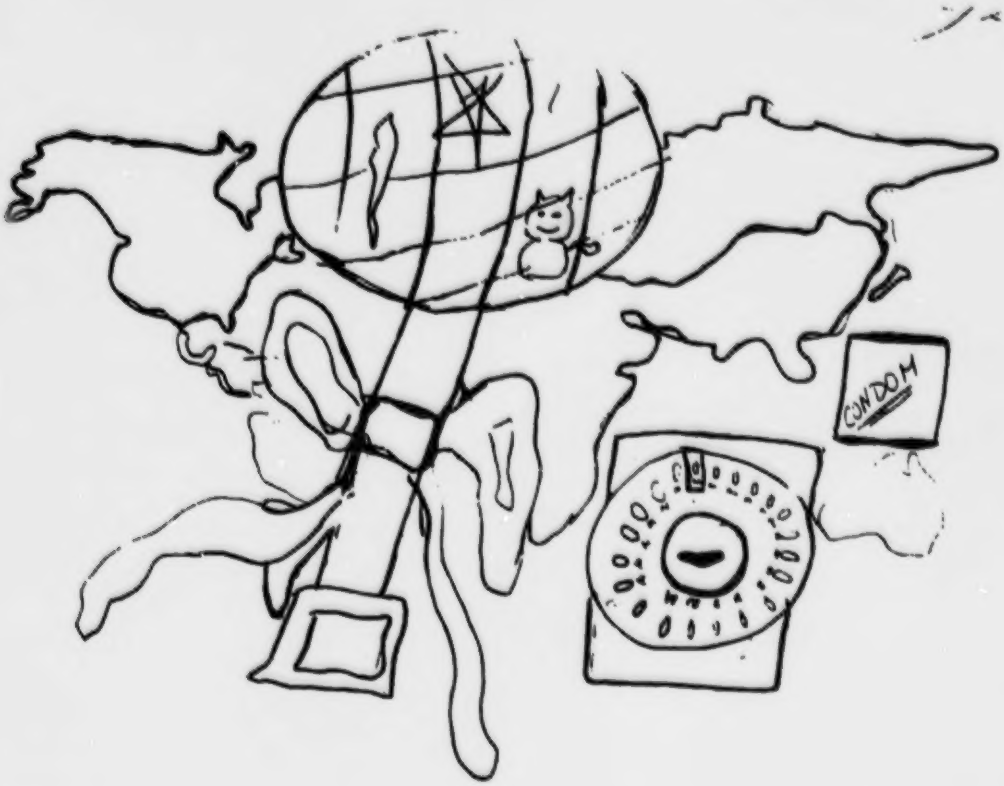


Figure 2.8: The "after" drawing of population explosion.

After reading an article on population explosion, students are challenged to explore many new concepts, as depicted in this picture. The world map indicates a global problem: the rattle shows the birth of children, and the influence of birth control is indicated. Clearly, this student's concept of population explosion expanded.

4. PReP (Pre-Reading Plan)

This structured brainstorming strategy allows the teacher to assess students' prior knowledge.

Procedure

This strategy follows these basic steps:

1. The teacher decides on the main ideas about a particular concept.

2. The teacher introduces a topic with a question: "Tell me anything that comes to mind when you think of … ?" (Jones et al., 1987, 45-46). This step could be modified slightly by showing a picture or reading a passage and then asking "What comes to mind when you see … ?" or " … hear … ?"

3. All responses are written on the blackboard or overhead projector.

4. The teacher asks, "What made you think of … ?", and discussion continues (Jones et al., 1987, 46). Students begin to connect what they know to the ideas of others.

5. The teacher asks, "Based on our discussion, have you any new ideas about … ?" (Jones et al, 1987, 46). Students begin to reformulate what they know, and the teacher gains a better understanding of students' prior knowledge.

Example

The class is beginning readings on nuclear chemistry.

- The teacher says, "Tell me anything that comes to mind when you think of *radioactivity*."
- The teacher writes all responses on the blackboard.
- The teacher then asks certain students, "What made you think of … ?" (The questions will depend on the responses.)

  e.g.. 1. What made you think of the term *half-life?*

  2. What made you think of *Chernobyl?*

  3. What made you think of *things that glow?*

  Based on students' responses, the teacher has the opportunity to clear up any misconceptions and to show students how familiar they already are with radioactivity.

PReP: Adapted from Langer, Judith. "Examining Background Knowledge and Text Comprehension," *Reading Research Quarterly* 19 (1984): 468–481. Used by permission of International Reading Association.

- The teacher finally asks, "Based on our discussion, have you any new ideas about radioactivity?"

Students' understanding of radioactivity could be strengthened if they are asked at this point to write down their own operational definition of radioactivity.

Summary

Learning occurs when we connect new information to what we already know. Unless we can dig deep and find relevant prior knowledge, we have nothing to "hang our hats on."

Prior knowledge strategies

- provide focus and interest for every student in the class
- allow students to activate what they already know about the topic, such as organization and vocabulary
- allow teachers to determine each student's entry-level knowledge and plan instruction accordingly
- allow teachers to clear up misconceptions about science and science concepts

References

American Association for the Advancement of Science, (1989).

Cook, D. *Strategic Learning in the Content Areas.* Madison, WI: Wisconsin Department of Public Instruction, 1993.

Driver, R. "Theory into Practice II: A Constructivist Approach to Curricular Development." *Development and Dilemmas in Science Education.* Ed. Peter Fensham. London, UK: The Falmer Press, 1988. 133–149.

Jones, B., A. Palincsar, D. Ogle, and E. Carr. *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas.* Alexandria, VA: Association for Supervision and Curriculum, 1987.

McConnell, S. "Talking Drawings." *Journal of Reading*, 36.4 (1992/3): 260-269.

Schraer, W., and H. Stoltze. *Biology: The Study of Life*. 5th ed. Needham, MA: Prentice Hall, 1993.

Thelen, J. *Improved Reading in Science*. 2nd ed. Ann Arbor, MI: Books on Demand, 1984.

Attachment 2.1

KWL Plus

Course ______________   Topic ______________

Known	Want to Know	Learned

Categories

KWL Plus: Jones, B., A. Palincsar, D. Ogle, and E. Carr. Strategic Teaching and Learning: Cognitive Instruction in the Content Areas. Alexandria, VA: Association for Supervision and Curriculum, 1987.

Attachment 2.2

Knowledge Chart

Course ______________ Unit ______________

What do you know about ________________?

Know now (draw):	**Know now (list):**

Need to know:

List what you have learned:	**Final concept map or drawing:**

Knowledge Chart: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

CHAPTER 3: BUILDING A SCIENTIFIC VOCABULARY

CHAPTER 3: BUILDING A SCIENTIFIC VOCABULARY

It has been said that students see and hear more new and specialized words in a high school science class than in a second language class. But are students really understanding the concepts that these terms represent?

To successfully learn scientific vocabulary … students must have both a definitional and contextual knowledge of that word (Stahl, 1985).

To successfully learn scientific vocabulary, students need both multiple and varied exposures to the essential words of that discipline. However, to understand these words well, students must have both a definitional and contextual knowledge of that word (Stahl, 1985).

One strategy often associated with teaching vocabulary is having students identify the new words in a reading and then having them look them up in a dictionary. Research indicates this to be the least effective strategy to use when teaching scientific vocabulary as this strategy requires only a definitional knowledge of the word. The student simply learns what the term means in relation to other words. Students need to process vocabulary in greater depth and develop contextual knowledge around it, which requires thorough and frequent usage of words (Stahl, 1985).

This chapter details two levels of vocabulary-building strategies (based on Bloom's taxonomy [Bloom, et al., 1956]):

- level one strategies promote exposure to words
- level two strategies require deeper processing of words

The level one and level two strategies outlined in this chapter are as follows:

Level One Strategies (promote exposure to words)

1. **Dictionary Method**
2. **Word Game Worksheets**
3. **Readings with Fill-in-the-blank Questions**
4. **Word Cycles Using the Listen—Think—Pair—Share (LTPS) Approach**

Level Two Strategies (require deeper processing of words)

5. **Generating Definitions**
   a. By Composing Sentences
   b. Using the Three-Point Approach
6. **Webs and Clusters**
7. **Sort and Predict**
8. **Compare and Contrast**

Although these strategies have been categorized as *level one* or *level two*, the level really depends on the depth to which they are used.

Some of the suggested strategies use a think sheet. Specific examples that use the sheets are also discussed. For ready-to-use, full-sized sheets, please see Attachments at the end of this chapter.

Level One Strategies

Level one strategies require students to use

- knowledge
- comprehension
- application thinking

Level one strategies can be used quite independently with a minimum of instruction or used simply as an activity. However, if the student is to use a strategy more effectively and apply it to more situations, the teacher must model both when and how to use it, and it must be used frequently.

1. Dictionary Method

Students are asked to find definitions for a given list of words from a dictionary or glossary.

This method simply exposes students to vocabulary; in Bloom's taxonomy this requires only knowledge.

Suggestions

Ask students to

- paraphrase the definition or even write their own definition
- write a sentence using the word that demonstrates the word's meaning
- write a sentence using the word and demonstrating either an historical or science-technology-society-environment connection

2. Word Game Worksheets

These worksheets

- generally require word recall by the students
- are employed to familiarize the students with a definition either at the knowledge or at the comprehension level

Formats

Word game worksheets are available in a variety of formats. Some are student or teacher generated, while others can be purchased.
These include

- crosswords
- word searches
- puzzles

The real advantage of this strategy is motivational as many students are intrigued by games and puzzles.

Suggestions

- Use a variety of worksheets to help students become familiar with the terms and their definitions.
- Recognize that most worksheets do not develop the students' contextual knowledge of vocabulary. Students do not always draw relationships between words, so provide students with opportunities to use words in new contexts.

3. Readings with Fill-in-the-Blank Questions

These worksheets allow students to form associations between words by their being selective and reading words in context. This reading approach can also strengthen contextual knowledge of vocabulary if it accompanies direct instruction (Stahl, 1983).

Formats

This type of worksheet usually has a few paragraphs of text with fill-in-the-blank questions following. Occasionally, a word search is included.

Suggestions

Have students create their own think sheets to process the vocabulary at a higher level.

4. Word Cycle Using the Listen—Think—Pair—Share (LTPS) Approach

This strategy develops a comprehensive understanding of a concept or a word. Students learn how terms are related, broadening their meaning. More is learned as students collaborate with others and share their knowledge.

This is probably the easiest and most popular level one strategy. For a blank copy of this format, refer to Attachment 3.1 at the end of this chapter. For more on Listen—Think—Pair—Share, see page 2.6.

Procedure

The teacher first *models* how to complete a Word Cycle using familiar vocabulary (a foods and tastes example is given in Figure 3.1). Students *listen* and may be asked to participate.

1. The teacher places the example Word Cycle on the overhead.
2. The teacher selects one word and writes it in any oval. A second word is then chosen and written in the oval beside. An explanation is given for why the words were selected and what their relationship is.

Word Cycle: *Reading—A Novel Approach* by Janice Szabos, 1984 © Good Apple. A Division of Frank Schaffer Publications, 23740 Hawthorne Boulevard, Torrance CA 90505.

3. That relationship is written in the connecting band. It might be a synonym, antonym, step in a process, or other connection. Be sure to stress that there is no one right answer. Many possibilities exist as long as relationships can be explained and justified.
4. A student continues the process, selecting a word, placing it in an adjoining oval, and explaining the connection to the class.
5. Students take turns going through the process until the cycle is completed.

Once the modelling is completed, the following steps are taken:

6. The teacher hands out the Word Cycle with current vocabulary (refer to Figure 3.2). This Word Cycle has essential and/or foundation words for the unit or topic area written in the centre of the cycle.
7. Students finish the Word Cycle alone. This is the *think* stage.
8. Students then pair up *(pairing)*. Often pairs are preselected to save time.
9. Each student discusses the cycle with his/her partner, defending choices made. This opportunity to use the scientific terms orally is important to vocabulary development.

The teacher brings the class back together after pairing is done.

10. Students take turns sharing their work with the whole class. Word Cycles are displayed and explained, or the class builds a Word Cycle together.

Suggestions

- Ask students to explain connections between terms and to defend their choices to the class.
- Use Word Cycles more frequently, and students' explanations will become more sophisticated and thorough.
- This strategy requires Bloom's level one application skills unless a lot of discussion is promoted. If discussion occurs, students start pointing out relationships, discriminating between terms, rearranging orders, and so on. These higher order thinking skills put Word Cycles into level two.

Examples

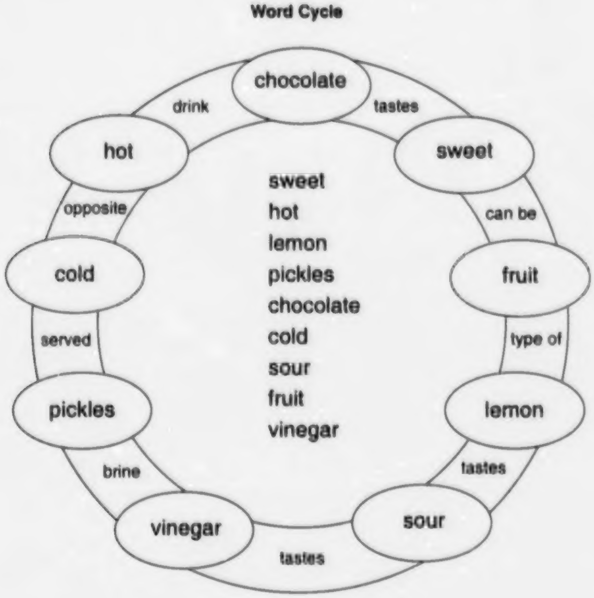


Figure 3.1: Foods and taste word cycle

Figure 3.2: Environmental science word cycle

Level Two Strategies

Level two strategies ask students to analyse, synthesize, and evaluate. These strategies are generally less think-sheet based and more student generated.

In using level two strategies, science teachers are required to question, probe, and facilitate discussion. This may require more work from both teacher and students, but the results are more satisfying as new words are read, written, and spoken.

5. Generating Definitions

Synthesis is required for students to create their own definitions (Bloom's taxonomy). Two ways to generate definitions will be reviewed

a. by Composing Sentences

b. using the Three-Point Approach

By Composing Sentences—Writing a sentence using essential words or composing a paragraph using foundation words is more challenging. As students design, compose, and rewrite, they create context for words and thereby develop a better understanding.

Using the Three-Point Approach—One strategy that goes beyond simply writing a definition is the Three-Point Approach (refer to Figure 3.3). In using this approach, the student must

- make connections
- create
- describe
- illustrate

For a blank copy of this frame, refer to Attachment 3.2 at the end of this chapter.

Procedure

Students explain a term or word in three ways; they

1. write a definition in the left column (they cannot copy this from a book)
2. list a synonym or example in the centre column
3. draw a picture or diagram in the right column

Suggestions

As with all strategies, this technique must be modelled. Students' abilities to use this strategy depend on teacher expectations. Providing anecdotal feedback as students learn to use the strategy will lead to improvements in student performance.

Examples

Example One: The three points for the fluoride ion are listed in Figure 3.3 below.

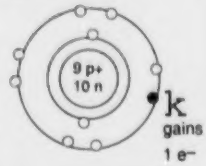
Definition	Word or Concept: Fluoride Ion	Diagram:
- ion formed from fluoride atom - anion - halide - gains one electron to become stable - oxidation number is 1^-	Synonym/Example: F^-	

Figure 3.3: Three-point approach for vocabulary

Example Two: Renal is a term used in human biology. By definition, renal pertains to the kidneys. The example could be a renal artery and the diagram could be of a kidney.

Three-Point Approach: Adapted from Simons, Sandra M. *Strategies for Reading Nonfiction*. Copyright © 1991 by Spring Street Press. Used by permission of the publisher.

6. Webs and Clusters

Semantic mapping is a superior technique for vocabulary instruction (Stahl, 1985). This includes making Word Webs and Word Clusters. Students draw relationships between words by looking for their similarities and differences.

Procedures

In a Word Web, a new word is placed in the centre of a page and other related words connected to it.

A Word Cluster puts more emphasis on a hierarchy based on which words belong together. Groups of terms are identified and clustered together. This is a good technique to use when brainstorming.

For those who want additional information, these strategies are reviewed in detail in *Chapter 4: Developing Scientific Concepts Using Graphic Displays.*

Suggestions

Both techniques can be modelled by the teacher and taught to the students. Sometimes students are surprised to see these strategies used in science.

NOTE: Mapping, an important strategy with many applications, is also covered in depth in *Chapter 2: Tapping into Prior Knowledge.*

Example

To understand the word *evaporate* in context, you can follow these steps:

- Put up a diagram of an open Erlenmeyer flask from which a liquid is evaporating (refer to Figure 3.4).
- Ask students for their observations and then question them about what they think is happening.
- As the answers come in, build a Word Cluster on the board.
- Ask the students where they would like the words placed in the cluster.
- If important words are missed, ask students how those missing terms relate to the diagram.
- Show a second diagram in which the system is closed (refer to Figure 3.4).
- After students interpret the diagram, add to the cluster.

- Ask students to compare the two diagrams and indicate what each would look like in 48 hours or consider the implications of using a different liquid. In doing this, students discuss terms like vapour, kinetic energy, pressure, equilibrium, phase, condense, surface, and volatility.
- Finally, have students identify what key words from the cluster are needed to describe evaporation.
- Then have students each write a definition for evaporation incorporating these words. For example, "evaporation is the conversion of surface molecules from a liquid to a vapour when they have sufficient kinetic energy to overcome intermolecular forces. A dynamic equilibrium can be reached between the liquid and vapour molecules in a closed system."
- Show a third diagram and use the same strategies to have students generate a definition for *boiling*.

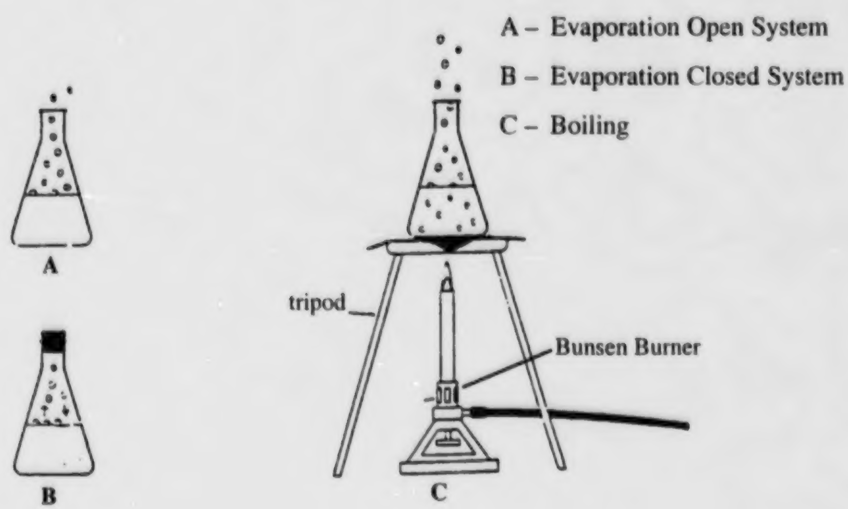


Figure 3.4: Examples of evaporation and boiling

7. Sort and Predict

Sort and Predict strategies allow the use of all the foundation words from a unit of study in one vocabulary strategy. An example is provided in Figure 3.5. For a blank Sort and Predict think sheet, refer to Attachment 3.3 at the end of this chapter.

Procedure

For this strategy, students work in small groups.

1. The teacher lists approximately 20 foundation words from the unit and gives think sheets to each group.
2. Groups develop four categories for the words, each with its own criteria.
3. Groups place the terms within each category so that each has at least three terms. Only one term may be put into two categories.

   (Note: To facilitate discussion, have each group work on one think sheet. Have students cut out the words and physically move them into piles.)
4. The teacher challenges students to make one unique and original category.

   Note: When students are first trying the strategy, the teacher might want to omit this step. This work continues until all the words are categorized and the categories are labelled.
5. Groups share their results with the rest of the class. Each group elects a spokesperson who indicates the unique category first and then talks about the other categories.
6. Using constructive criticism, the teacher encourages students to give each other feedback on their choices.

Suggestions

This technique can be used at any point in a unit:

- If it's used at the beginning, encourage the students to go back and recategorize the words as they learn more about them.
- If it's applied as a review, ask students to use terms about which they are uncertain. Have them complete the work on chart paper and display these throughout the room.

Sort and Predict: Adapted from Brownlie, F., and S. Close. *Beyond Chalk and Talk: Collaborative Strategies for the Middle and High School Years.* Copyright © 1992. Pembroke Publishers Limited. Used by permission of the publisher.

Example

UNIT: Kinematics

SORT and PREDICT

TOPIC: Physic

Directions
Read the list of words on the left and sort them out into four different categories by placing them in the boxes. For the words that you are unsure of, predict which category each would belong to. When selecting categories, try to make the fourth category different from any other category that the rest of the class would think of. Use your creativity; be original! You may use <u>one</u> word in more than one category.

<table>
<tr>
<td rowspan="2">scalar
displacement
resultant
component
tangent
acceleration
kinematics
vector
tip-to-tail
speed
distance
velocity
direction
time rate of change
magnitude
instantaneous
parallelogram
meters/second ^{2}
heading
sine</td>
<td>A. <u>Graphing</u>
tip-to-tail
resultant
component
scalar
parallelogram

* methods & products</td>
<td>B. <u>Math</u>
tangent
sine
kinematics

* first two are needed for last</td>
</tr>
<tr>
<td>C. <u>Kinds of Measurement</u>
distance speed
velocity
acceleration
meters/second ^{2}
instantaneous
displacement

* units and used to calculate measurements</td>
<td>D. <u><</u>
vector
direction
magnitude
heading

* direction and magnitude are part of heading</td>
</tr>
</table>

Figure 3.5: Sort and Predict for a kinematics unit in physics

Sort and Predict Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

8. Compare and Contrast

Sometimes the essential words are taught in very similar ways. These are the terms students have to compare and contrast on a test. Unfortunately, because students often have limited experience with comparing and contrasting scientific terms, they tend to define rather than compare words.

Procedure

1. The teacher models how to complete the Compare and Contrast think sheet using an example on the overhead. For a blank Compare and Contrast think sheet, refer to Attachment 3.4 at the end of this chapter.
2. The teacher adds students' suggestions to the sheet.
3. Students build the final statement last. Students can pair up to develop their statements. Summarizing the compare section and then the contrast section can help them build their final statements.

Suggestions

- Use Compare and Contrast think sheets for many applications beyond teaching vocabulary. They are useful for analysis of concepts and for certain text readings as well.
- As with many of the strategies in this section, the Listen—Think—Pair—Share approach can be used in constructing Compare and Contrast think sheets. After modeling how to use the approach, have each individual fill out a sheet during the think stage. Then students can pair, discuss, and share their work with the class. The quality of student responses will improve as they practise this strategy.
- When students are familiar with the strategy, use a Compare and Contrast think-sheet question for evaluation purposes.

Examples

Example One

To reinforce learning, the teacher can have students compare *evaporation* and *boiling* by using a Compare and Contrast think sheet. This strategy will help students interpret diagrams and clusters (see Figure 3.6).

COMPARE AND CONTRAST

Unit: Solutions

Topic: Phase Changes

COMPARE

How are evaporation and boiling **alike?**

- both are dynamic
- deal with intermolecular forces and KE
- collisions are involved
- both are conversions
- molecules in both are attracted to each other (intermolecular forces)
- both deal with vapour pressure
- liquids boil and evaporate at different rates

CONTRAST

How are evaporation and boiling **different?**

evaporation	boiling
- conversion of surface molecules from liquid to vapour - vapour escapes in open system - doesn't require temperature change - molecules with high KE escape as vapour leaving molecules with lower KE - leaves surface feeling cool - dynamic system	- conversion of molecules through-out liquid, from a liquid to a gas - an increase of heat or a decrease of pressure is required - deals with vapour pressure inside bubbles and atmospheric pressure - gas escapes in open system - vapour pressure = atmosphere pressure - liquid can be hot or cold

Write a statement to compare and contrast the two terms, concepts or events.

Evaporation and boiling are dynamic, occur at different temperatures and involve collisions and KE. They are conversions when the intermolecular forces between molecules are broken (overcome). Evaporation occurs when intermolecular forces are broken at the surface, whereas in boiling, it occurs throughout the liquid. In evaporation, vapour escapes and in boiling, gas forms.

Figure 3.6: Student compares and contrasts evaporation and boiling

This analysis of the boiling and evaporation process goes far beyond simply looking these terms up in a dictionary.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

By doing this, students become aware of several phenomena in the boiling/evaporating system:

- Adding heat affects the kinetic energy.
- Vapour is created in bubbles throughout the liquid.
- A dynamic equilibrium cannot be achieved since vapour pressure is not constant.

Example Two

In biology, *diffusion* and *osmosis* are both methods of passive transport of substances at the cellular level. Students often confuse these two terms. One vocabulary strategy that is very effective in distinguishing between the two is to use a Compare and Contrast think sheet, as outlined in Figure 3.7 below.

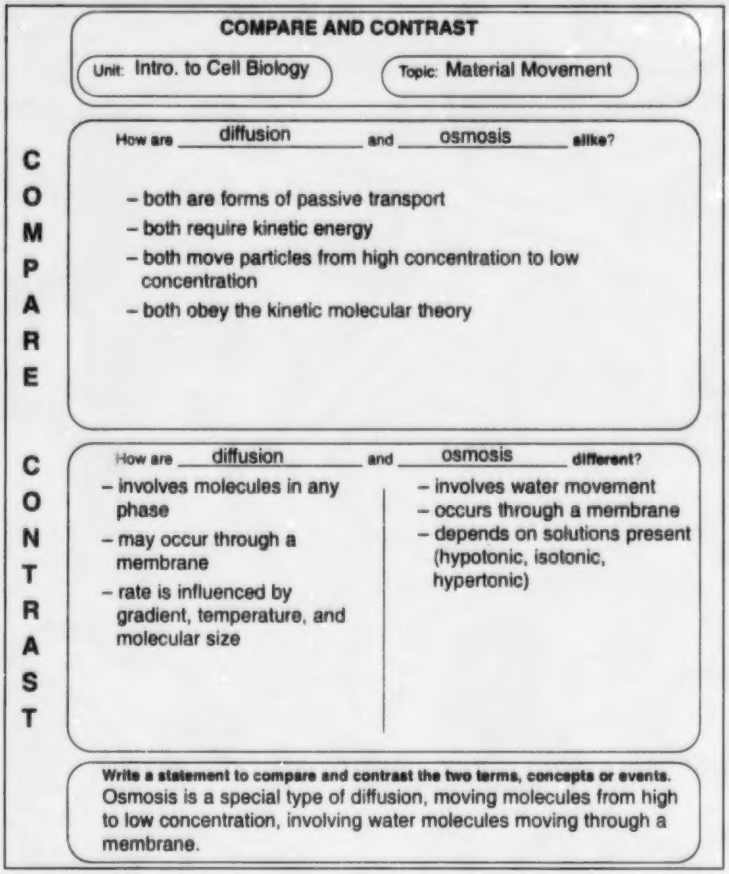


Figure 3.7: Compare and Contrast for diffusion versus osmosis in a cell biology unit

In Figure 3.7, a student identified the similarities (compare) of diffusion and osmosis and listed their differences (contrast). No lines were drawn on the sheet in case the student wanted to make drawings. In the bottom frame, students were asked to generate a statement comparing and contrasting these two terms.

Strategic Teaching with Level One and Level Two

As teachers plan how to teach each unit, they should keep in mind the various strategies they can use to teach the foundation words. Essential terms require complex processing and need both level one and level two strategies. Use of both strategies should help students develop both definitional and contextual meanings for words.

For example, in a life science unit involving cancer, one can try doing the following:

1. Introduce the unit with a Sort and Predict strategy.
2. Then use a Compare and Contrast think sheet to look at normal and abnormal cells.
3. Follow with a Word Cycle for types and stages of cancer terms.
4. Finish with another Sort and Predict so that students see how their understanding of terms has developed.

Both levels of strategies can be used effectively in the classroom as students need multiple and varied exposure to words.

Where to Begin

Several pointers for implementing vocabulary-building strategies are offered here.

- *Identify which words are essential and which are needed to simply get through the reading or the lab.*

  Years from now, what two or three words from each unit would you want students to use effectively? Homeostasis and metabolism are terms that come to mind for the life sciences. Sustainable development is stressed in environmental units. Velocity, inertia, mole, and valence are important words in the physical sciences.

  Essential words can be kept in mind throughout the teaching year by introducing them in each unit and connecting them to other terms.

- *Be conscious of using strategies that help students learn both essential and foundation words throughout the lesson.*

  The literature shows support for preteaching vocabulary to aid reading comprehension (Stahl, 1983). You can do this in the accessing *(pre-reading)* phase of the lesson by exposing students to the terms. Vocabulary teaching should then continue during the acquire *(during-reading)* and apply *(post-reading)* phases.

- *Continue to expose students to many new terms, but focus on the essential and foundation terms with the vocabulary strategies.*
- *Provide students with feedback as they apply the vocabulary strategies.*

Summary

Teachers can help students build scientific vocabulary by employing a variety of teaching strategies at both the exposure and deeper processing levels (levels one and two, respectively). As students interact with scientific words, their vocabulary develops beyond definitions and is learned at a deeper level.

References

Bloom, B.S., et al. *Taxonomy of Educational Objectives: Handbook 1, Cognitive Domain.* New York, NY: D. McKay, 1956.

Brownlie, F., and S. Close. *Beyond Chalk and Talk.* Markham, ON: Pembroke, 1992.

Duin, A. H., and M.F. Graves. "Intensive Vocabulary Instruction as a Prewriting Technique." *Reading Research Quarterly,* 22.3 (1987): 311-330.

McKeown, M. "The Acquisition of Word Meaning From Context by Children of High and Low Ability." *Reading Research Quarterly,* 20.4 (1985): 482-496.

McKeown, M., and I.L. Beck. "Learning Vocabulary: Different Ways for Different Goals." *Remedial and Special Education*, 9.1 (1988): 42-46.

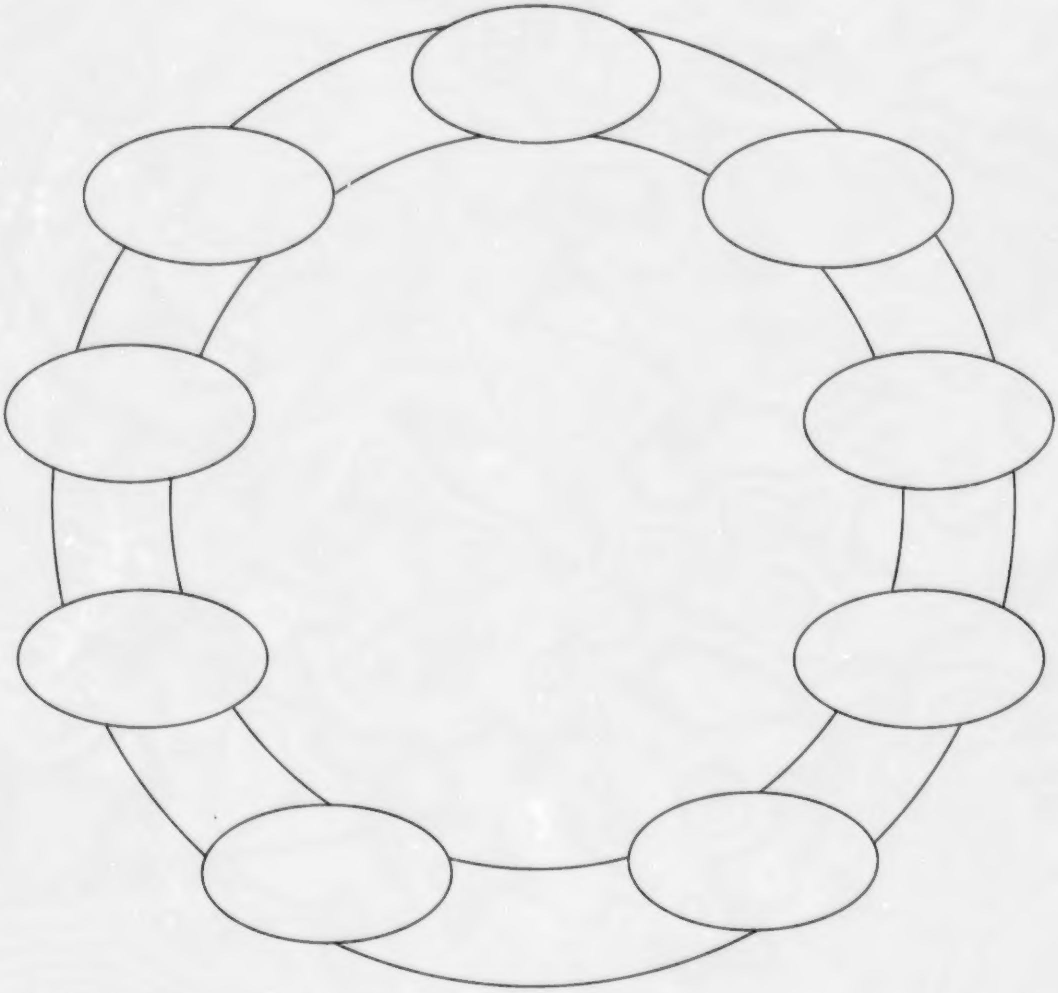
Stahl, S. "Differential Word Knowledge and Reading Comprehension." *Journal of Reading Behaviour,* 15.4 (1983): 33-50.

___. "To Teach a Word Well: A Framework for Vocabulary Instruction." *Reading World,* 24.3 (1985): 16-27.

Tarasoff, M. *Reading Instruction That Makes Sense.* Victoria, BC: Active Learning Institute (1993).

Attachment 3.1

Word Cycle



Directions:

Read the list of words in the circle above. Select one word and place it in any oval. In the next oval, place another word that is related to the first. They could be synonyms, antonyms, steps in a process, examples of something, and so on. Be prepared to finish the statement "Word A is related to word B because . . . ." Write a note on the band in between the words to remind yourself of the relationship. Continue this process until you have placed all the words. Plan ahead; the last few words will be tricky to place.

Word Cycle: *Reading—A Novel Approach* by Janice Szabos, 1984 © Good Apple. A Division of Frank Schaffer Publications, 23740 Hawthorne Boulevard, Torrance CA 90505.

Attachment 3.2

Three-Point Approach for Words and Concepts

Definition	**Word or Concept**	Diagram
	Synonym/Example	

Definition	**Word or Concept**	Diagram
	Synonym/Example	

Definition	**Word or Concept**	Diagram
	Synonym/Example	

Definition	**Word or Concept**	Diagram
	Synonym/Example	

Three-Point Approach: Adapted from Simons, Sandra M. *Strategies for Reading Nonfiction.* Copyright © 1991 by Spring Street Press. Used by permission of the publisher.

Attachment 3.3

Sort and Predict

Unit ____________________ Topic ____________________

Directions:

Read the list of words on the left and sort them into four different categories by placing them in the boxes. For the words that you are unsure of, predict which category each would belong to. When selecting categories, try to make the fourth category different from any category that the rest of the class would think of. Use your creativity; be original! You may use **one** word in more than one category.

	1. ____________	2. ____________
	3. ____________	4. ____________

Sort and Predict Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Attachment 3.4

Compare and Contrast

Unit ______________________ Topic ______________________

C O M P A R E	How are ______________ and ______________ **alike**?

C O N T R A S T	How are ______________ and ______________ **different**?	

Write a statement to compare and contrast the two terms, concepts, or events.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

CHAPTER 4: DEVELOPING SCIENTIFIC CONCEPTS USING GRAPHIC DISPLAYS

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Science students must not only construct knowledge, they must relate it to their existing knowledge framework and to the real world. How can teachers facilitate comprehension and help students organize their thoughts?

Many students seem to have an innate ability to organize. "Humans tend to cluster together sets of facts into chunks we call 'concepts'" (Sizmur, 1994, 120). Teachers can help students improve their concept-building abilities by offering them graphic strategies, namely Mind Maps, Concept Maps, and Frames. These strategies help students identify concepts and recognize links between them.

- Mind Maps help students activate prior knowledge.
- Concept Maps guide students as they identify and connect main ideas.
- Frames help students focus on specific aspects of a concept.

This chapter describes maps and frames and provides strategies for their implementation.

Uses for Maps and Frames

Using maps and frames in the science class is related to both processing information (process) and producing a knowledge framework (product).

Using maps and frames in the science class is related to both processing information *(process)* and producing a knowledge framework *(product).*

When students create maps or complete frames they *process* information, as they

- "relate new information to prior knowledge"
- "store and retrieve information"
- "generate elaborate ideas"
- "depict relationships between facts and concepts" (Bellanca and Fogarty, 1992, 9)

These completed maps or frames are the *product* from which teachers determine what their students are thinking.

In addition, teachers can use maps and frames to

- organize lessons
- outline readings
- review units
- set goals with students
- depict relationships between concepts

Applications of these organizers are as limitless as the types that are created. The most beneficial uses occur, however, when students generate their own maps or frames.

Maps and frames improve the way one organizes, outlines, and reviews information.

Maps and frames improve the way one organizes, outlines, and reviews information. They develop students' thinking and challenge their skills at either end of Bloom's taxonomy (Bloom, et al., 1956). At one end, they improve the way students retrieve information and organize it. And at the other end, as students complete a Concept Relationship Frame or a Concept Overview Frame (refer to Attachments at the end of the chapter), they are required to analyse, synthesize, and evaluate.

Maps and frames can enhance learning throughout a lesson—they can be used

- *before* a reading or problem-solving activity, as an advance organizer
- *during a* reading or problem-solving activity to help focus students' attention on what is important
- *after* a lesson to summarize, sequence, and integrate information (Jones, Palincsar, Ogle and Carr, 1987, 37)

Maps and frames help all students, not just the weak ones (Jones et al., 1987). The frequency of use and variety presented will depend on the strengths of each class. In particular, they are popular with visual learners, typically comprising the majority of a class.

This chapter reviews

- Mind Maps
- Concept Maps
- Frames

Maps are diagrams that show how people perceive relationships among concepts. They are powerful diagnostic tools for revealing student beliefs. When maps are used early in the study of a topic, they probe students' ideas (Mind Maps). When implemented later, they monitor conceptual change (Concept Maps). Missing links can also point to weaknesses in the structure of lessons.

Mind Maps

Mind Maps are semantic maps or spider maps. They allow for an unrestricted flow of thoughts as students write down all they know about a topic's main idea.

- At the *beginning* of a lesson, students identify what they already know (activate prior knowledge).
- Mind Maps used *later* in a lesson, help students organize and summarize what they have learned.

How students organize information depends on whether they use the Cluster or Web strategy. Clusters show natural groupings, whereas Webs emphasize connections among terms. Clusters usually generate more words, while Webs have more arrows. These strategies are described in detail below.

Once students are taught how to apply the Cluster and Web strategies, they can use them interchangeably. However, students may have preferences, depending on the concept studied.

The Mind Map strategies outlined include

1. **Cluster**
2. **Web**
3. **Mind Map Using the Listen—Think—Pair—Share Approach**

1. Cluster

(Pre-reading or pre-writing strategy)

With this strategy, students can

- focus and begin to explore the material in the lesson
- consolidate their background knowledge
- show what mental associations they may have in relation to the concept

Procedure

1. The teacher gives students a key word or concept.
2. Students write this key word or phrase in the centre of a page and then circle the word.
3. Students quickly jot down words or phrases they associate with that key word. These associations form "branches," with one association leading to another until students exhaust their train of thought.
4. Students return to the key word and start a new branch to create a new cluster of ideas.
5. Students continue writing clusters of ideas until the concept forms clearly enough in their minds that they want to start writing about it.

   At this point, a *shift* occurs—students quit making "idea branches" and actually start writing about an idea they feel motivated to write about. This shift is important if pre-writing is the main purpose of the exercise.

Examples

Figures 4.1 and 4.2 show two samples using the Cluster strategy written by different students on the same topic. Note the advantage to having students write a short summary of their thoughts, as misconceptions can then be identified and corrected.

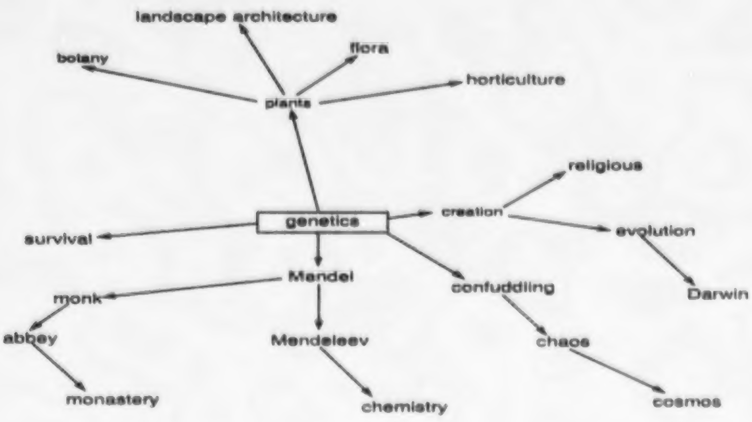


Figure 4.1: Student Mind Map: Cluster for genetics

Student Summary: The theory was that the universe was created from a "big bang." From there, earth was created. You could think of it as one very large evolving cell, producing and bringing forth new and independent things. Then came the formation of man and animals, each evolving from single cells with their own characteristics and mechanisms for survival.

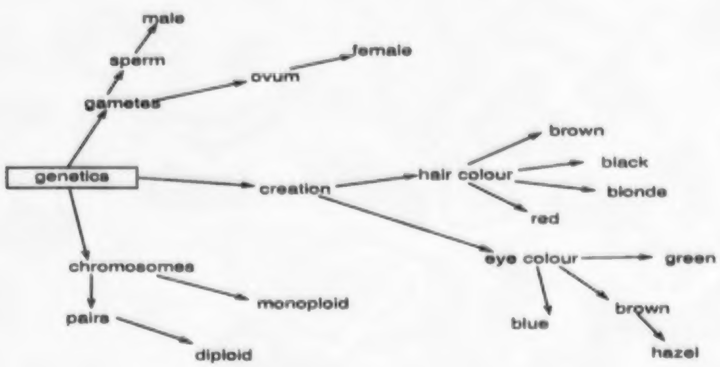


Figure 4.2: Student Mind Map: Cluster for genetics

Student Summary: Gametes are any sex cell (obviously male or female, as those are the two most common sexes). They are produced through or by a process called mitosis (asexual reproduction). Gametes may also be cells of both sexes (again, most likely male and female) so that when mitosis (cell division) occurs, you get another cell of either male or female gender.

2. Web

"Perhaps the most widely used cognitive organizer is the Web, which targets a concept and provides structures for analysing attributes" (Bellanca and Fogarty, 1992, 9). Terms in a Web can be concepts, events, objects, laws, themes, characters, classroom activities, or any other set of interrelated items.

Procedure

For a given set of terms, students

1. write down each term on separate small pieces of paper
2. arrange these terms on a page, considering each term separately and then their relation to each other
3. link related terms with a line
4. write the nature of the link on the connecting line

Suggestions

- When introducing students to the Web strategy, begin with a familiar topic in which the links are definitional, such as atoms, elements, and so on.
- Give students four to six terms initially, working up to seven to ten terms for later tasks.
- Require that students organize their own layout. Stress that there is no one correct answer but that students should be able to explain and justify the connections made.
- As students acquire skills in creating Webs, ask them to draw Webs using terms significant to them.

Example

The Web in Figure 4.3 illustrates possible linkages among force, motion, and energy.

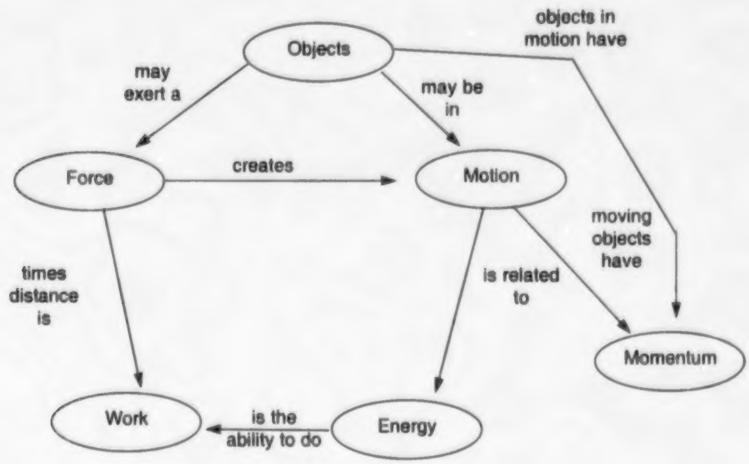


Figure 4.3: Web for force, motion, and energy

In this example, some ideas are clearly linked, while other relationships among the concepts of energy, momentum, and work are perceived in a superficial way. This may indicate the need to strengthen these connections.

Class Exercise

Ask students to construct a Web using the following words: *oxygen, aerobic respiration, sugar, ATP, rest, carbon dioxide, heat, water, chemical bond energy, activity, high energy phosphate bonds, chemoreceptors, medulla oblongata, muscle contraction.*

Student instructions:

1. Begin by placing a word somewhere on the page so that the other words can be placed in relation to this first word.
2. Cluster groups of related words.
3. Connect the words and explain their relationship to one another.

3. Mind Map Using the Listen—Think—Pair—Share (LTPS) Approach

This approach

- stimulates thinking
- focuses group discussions
- helps students see other points of view or major clusters they might have otherwise missed (Cook, 1993)

Procedure

1. The teacher introduces a topic.
2. Students listen to the teacher's introduction and directions and think about the topic.
3. Students make a cluster or a web on their own.
4. Students explain their Mind Map to a partner.
5. Students share their maps with the whole class.

Suggestions

Do not overuse the technique and try to vary the context in which it is used. This will maximize its effectiveness in stimulating the students' reflective thinking. For more on Listen—Think—Pair—Share, see page 2.6.

Concept Maps

Concept Maps are like Mind Maps in that they highlight clusters of ideas and the connections between them. They differ from Mind Maps in that the connections follow definite patterns, such as a chronological order.

The Concept Map strategies outlined include

4. **Category**
5. **Chain**
6. **Hierarchy**

These strategies are followed by a discussion to guide teachers in selecting the appropriate strategy.

4. Category Concept Map

This map is used to organize information presented in a lecture, video presentation, or reading.

Procedure

In this strategy, the main idea or concept is contained in a circle or a square or is represented by a picture and placed in the centre of the map. Lines or arrows connect the main idea to categories and subcategories. The farther it is from the centre, the more specific and detailed the information becomes (refer to Figures 4.4 and 4.5).

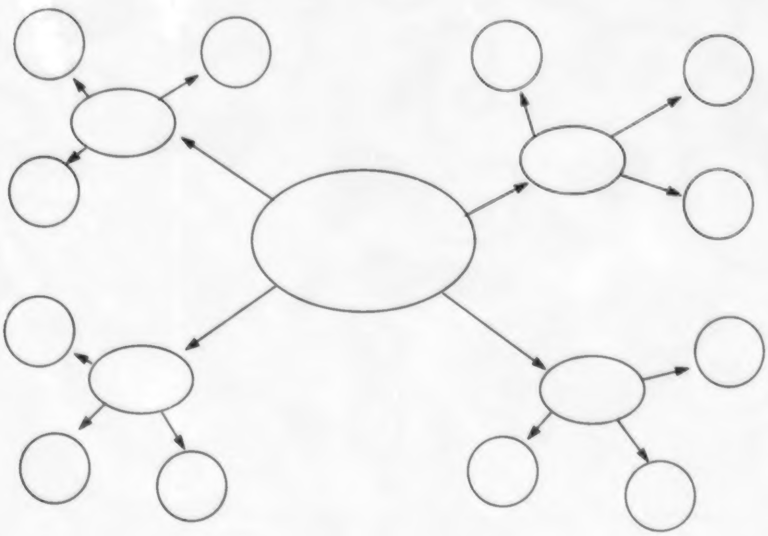


Figure 4.4: Category or thematic Concept Map

Teachers can begin creating a Category Concept Map with their class with the steps outlined below:

1. Give each student a copy of a blank map. Place a blank map on the overhead projector.
2. Write the key concept in the centre circle on the overhead copy.
3. Brainstorm with the students for related terms and list these words beside the map. This list is useful to orient students and to help poor spellers.
4. Lecture, show a video, or assign a reading.
5. Stop frequently so that students can independently fill in details on their maps.
6. Continue until all the material has been presented and the map is complete.
7. Have students share the maps as part of the Listen—Think—Pair—Share approach (see page 2.6).

Suggestions

- When first introducing this technique, give students the main categories.
- Before assigning a reading, have the students preread or scan the material and list the main categories (Cook, 1993).
- If students are listening to a lecture or watching a video, consider stopping after a few minutes and brainstorming to identify the categories covered so far. Then, ask them to add the details.
- Design a variety of Category Concept Maps with different numbers of categories. Either assign a particular map or allow students to select a map.

Example

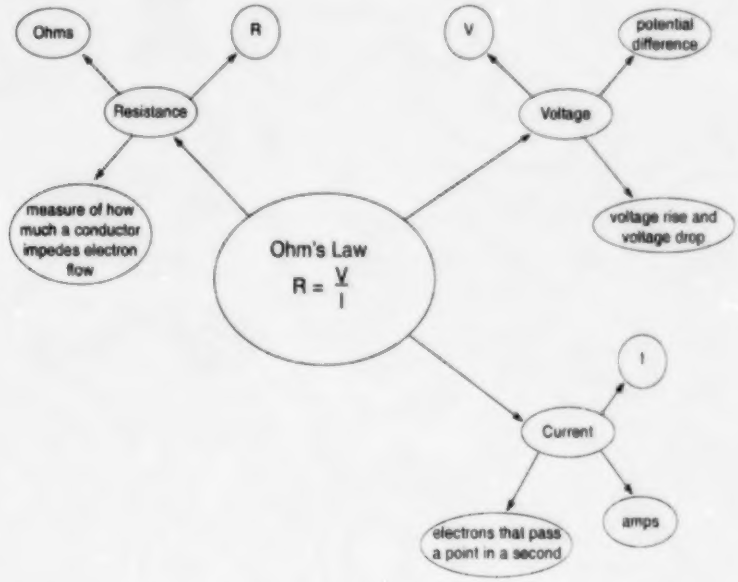


Figure 4.5: Categories of thematic Concept Map for current electricity

5. Chain Concept Map

The Chain Concept Map organizes

- steps of a process (or cycle)
- events in chronological order

This strategy is useful for reviewing material already learned. Students often use their notes or text to find the sequence of steps.

Procedure

The Chain Concept Map sets out sequential information in a series of boxes linked by arrows (Jones et al., 1987). The number of boxes or circles depends on the number of steps (refer to Figure 4.6–4.8). When a cycle is to be mapped, the circles or boxes should be linked in a continuous chain (refer to Figure 4.9).

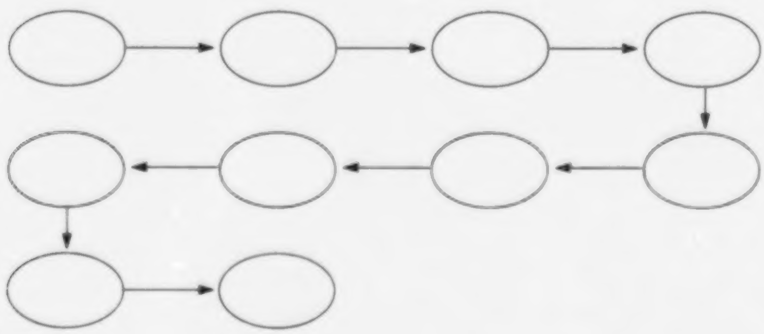


Figure 4.6: Chain or Sequential Concept Map

The teacher assists students by giving them the first step for their Chain Concept Maps. After that, students

1. fill out the remaining steps on their own
2. compare their completed maps with those of a partner
3. memorize the order of the steps

The teacher may choose to quiz students immediately upon their completion and again a few days later.

Suggestion

Use these student-created maps as study sheets. They are useful for that purpose.

Examples

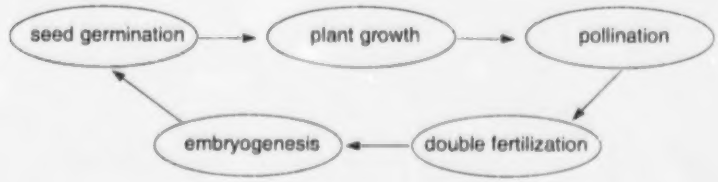


Figure 4.7: Chain or Sequential Concept Map for angiosperm life cycle

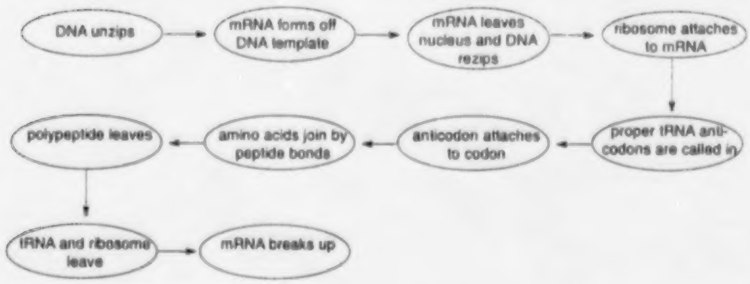


Figure 4.8: Chain or Sequential Concept Map for protein synthesis

6. Hierarchy Concept Map

The objective of this strategy is to organize information in a multi-level outline or hierarchy. For example, a plant or animal dichotomous key uses a hierarchical structure.

Suggestions

When teaching students to use these maps, stress two ideas:

- Information is arranged from general to specific.
- Maps can be read from general to specific or in reverse order.

A variety of Hierarchy Maps is available depending on the number of choices at each level (refer to Figures 4.9 and 4.10). Teachers and students will likely have to develop their own maps for some situations.

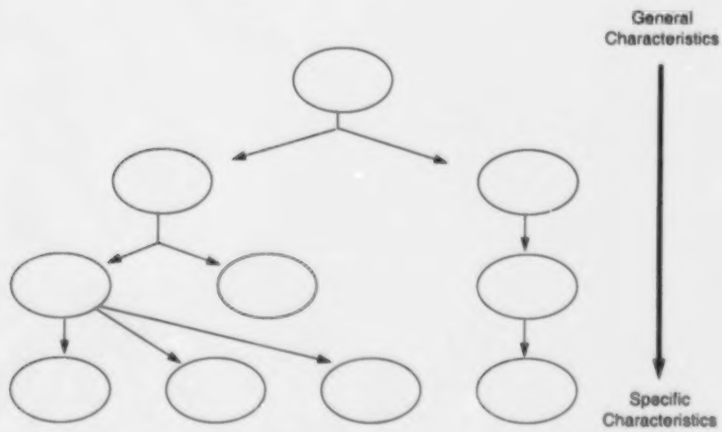


Figure 4.9: Concept Hierarchy Map

Example

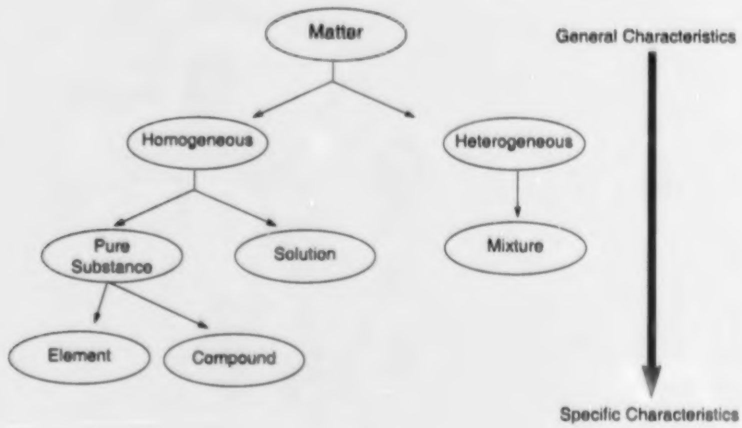


Figure 4.10: Concept Hierarchy Map for classification of matter.

In this map,

- "matter" is level one
- "homogeneous" is level two
- "solution" is level three
- "compound" is level four

A compound has all the characteristics of the levels above it, that is, pure substance, homogeneous, and matter.

Discussion: Which Concept Map Should You Use—Category, Chain, or Hierarchy?

To decide which Concept Map to use, examine the concepts being taught and identify the pattern. Select the appropriate map for the concept. This may be difficult at first. If so, use the Category Concept Maps—most concepts can be examined with this map.

Concept pattern topics are suggested below:

Category	energy, DNA, chemical reactions, pressure, biomes, chemical bonding, cells, cancer, types of asexual reproduction, nutrients, solutions, fundamental forces of nature, types of fields, current electricity
Chain	operation of a four-stroke engine, microscope slide, preparation & staining, steps in DNA replication, lock and key theory of enzymatic action, blood flow through the heart, operation of laboratory equipment, filtrate flow through a nephron, operation of wet and dry cells
Hierarchy	animal and plant taxonomy, classification of matter, body organization, food pyramids, characteristics of elements, organic substances

Suggestions

- At first, give students prepared map outlines with empty circles or squares. Students will then concentrate on identifying key concepts and the pattern that connects them.
- Expose students to a variety of Concept Maps so they can learn to differentiate among them. After a particular reading, video presentation, or lecture, model the use of a particular concept map.
- When students are familiar with Concept Maps, they will begin to construct them independently, deciding how many categories they need or recognizing that the information has a natural hierarchy.

Frames

Depending on the focus of the lesson, a frame, rather than a map, may be a better graphic strategy.

Frames differ from maps in that they do not emphasize patterns. Most frames fall into the broad category of concept organizers, while others examine concept relationships. With these concept frames, students learn to analyse a concept in their own words, as frames use sets of questions or categories of information to aid understanding. Another advantage of frames is that they allow students of different abilities to work on the same material at the same time.

A Fact-Based Article Analysis Frame helps students generate questions, list facts, identify key vocabulary, discuss relevance, and summarize articles (refer to Attachment 4.6 at the end of this chapter).

Another frame, called the Laboratory Report Outline, helps students organize themselves before, during, and after an experiment. Using this frame, students learn to identify the purpose of each step.

In general, students use frames to

- draw on relevant knowledge
- review concepts
- consolidate information
- give examples
- write a reaction
- understand relationships (compare-contrast, problem-solution, etc.)

The frames outlined in this chapter include

7. **Concept Relationship Frame**
8. **Concept Organizer Frames**
    - **Concept Frame**
    - **Concept Overview**
9. **Laboratory Report Outline**
10. **Article Analysis Frames**
    - **Fact-Based**
    - **Issue-Based**
11. **Note Frame**

7. Concept Relationship Frame

A Concept Relationship Frame is designed to examine particular associations between concepts (refer to Figure 4.13), such as

- cause/effect
- problem/solution
- either/or
- compare/contrast

Students have trouble recognizing these associations and often resort to a superficial analysis. Using a frame helps them examine relationships in more detail. Once students are familiar with the frame, their understanding has more depth.

Sample Applications

Using the same frame in a variety of ways allows students to practise examining relationships. For example, students could examine

- the cause and effect of electrical shocks
- charging either by conduction or by induction

Several compare/contrast examples include

- current and static electricity
- conductors and insulators
- series and parallel circuits

Procedure

As depicted in Figure 4.11 below, the Concept Relationship Frame has several sections:

- Make the distinction between
- Two relationship columns
- Write a summary statement

Changing the problem statement in the first section and each column heading, allows the same frame to be used for any relationship. For a full size blank copy of this frame, refer to Attachment 4.1 at the end of this chapter.

Concept Relationship Frame: Adapted by JoAnne Caldwell, Ph.D. Cardinal Stritch University, Milwaukee, WI. Used with permission.

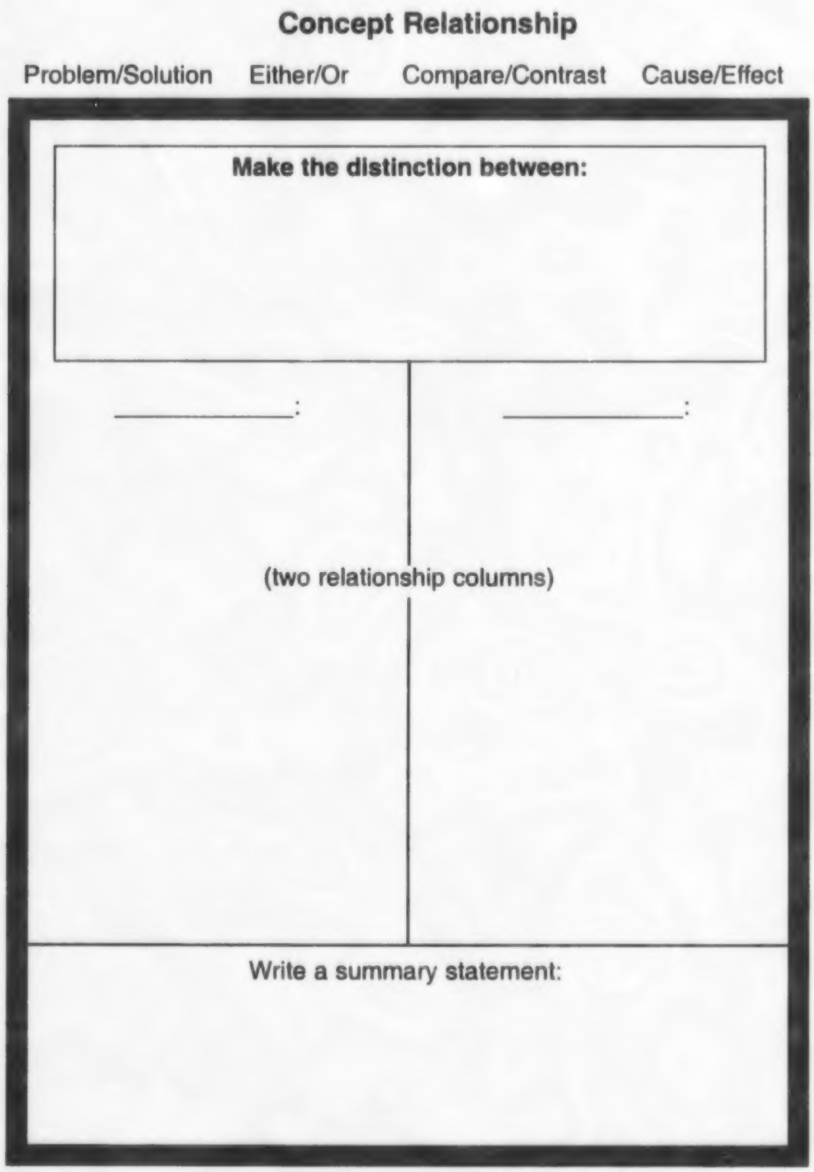


Figure 4.11: The Concept Relationship Frame

Example

In Figure 4.12, a Concept Relationship Frame is given to examine a problem-solution relationship in electrostatics. The first section outlines the problem and gives directions for completing the rest of the map. This problem requires some investigation.

Concept Relationship

Problem/Solution Either/Or Compare/Contrast Cause/Effect

Make the distinction between

Whenever any charged object is brought near a neutral one, a puzzling phenomenon occurs: the neutral object is first attracted and then repulsed. Test this in the laboratory and then complete the following analysis. Indicate what you found out by observation, reading and discussion.

PROBLEM:

— we rubbed a glass rod with a silk cloth and brought it near a neutral pith ball suspended on a thread

— at first the pith ball moved toward the rod

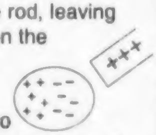
— once it touched the rod, it moved rapidly away

— if we removed the rod without touching the pith ball and later brought the rod back, the pith ball was attracted again

SOLUTION:

— rubbing the glass rod with the silk cloth gave the rod a positive charge because the electrons left the rod for the silk

— the electrons in the pith ball moved towards the rod, leaving a positive charge on the opposite side (it is temporary)



— opposites attract, so the pith ball went toward the rod, but when they touched, the electrons in the pith ball went to the rod, leaving the pith ball positively charged

— the positive pith ball repelled the positive glass rod

Write a summary statement:

Neutral objects are attracted to charged objects because the electrons within the neutral object temporarily align due to the influence of the charged object. Electrons are evenly spread out when the charged object leaves.

Figure 4.12: Problem/solution Concept Relationship for electrostatics

8. Concept Organizer Frames

Concept Organizer Frames (refer to Figures 4.13 and 4.14) are excellent tools for developing an understanding of a concept. Each box focuses on different aspects of the concept. By examining these aspects, the student can attain a more complete picture of the concept.

Two different frames are outlined in this handbook:

- Concept Frame
- Concept Overview

Students fill out these frames after they've studied a concept and are ready to describe it in detail. They often benefit by sharing these in a Listen—Think—Pair—Share situation. Completed frames may be used as study sheets. Examples of the Concept Frame and Concept Overview follow. For blank copies of these frames, refer to Attachments 4.2 and 4.3 at the end of this chapter.

Examples

Figure 4.13 illustrates a completed Concept Frame for *aliphatic hydrocarbons*. This sheet describes the characteristics of the concept using words and an illustration before the definition is stated.

CONCEPT FRAME

Concept:
Aliphatic Hydrocarbons

Characteristics:
- contain C and H atoms
- have isomers
- can be straight-chained or branched
- can be saturated with H atoms
- can have functional groups attached
- can have single, double, or triple bonds
- unique naming system based on number of carbon atoms in main chain and bond types
- carbon atoms can form 4 bonds

Examples:

butane C_4H_{10}

butene C_4H_8

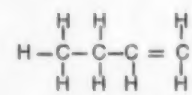
butyne C_4H_6

if you add the functional group – OH to butane, you get butanol

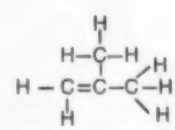
What is it like?
- building with lego
- family trees where names are related

What is it unlike?
- Aromatic hydrocarbons that contain benzene rings
- Cyclic Hydrocarbons

Can you illustrate it?
- structural formula for butene (C_4H_8)



- structural formula for 2-methyl propene (C_4H_8)



Definition:
Aliphatic hydrocarbons are straight-chained or branched organic compounds containing hydrogen and carbon atoms. They may be saturated or not.

Figure 4.13: Student's Concept Frame for aliphatic hydrocarbons in organic chemistry

The concept of *protein synthesis* has been examined using the Concept Overview in Figure 4.16. One strength of this frame is that students must create an analogy to "link familiar concepts with new information" (Cook, 1993, 125).

Concept Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

CONCEPT OVERVIEW

Key Word Concept:

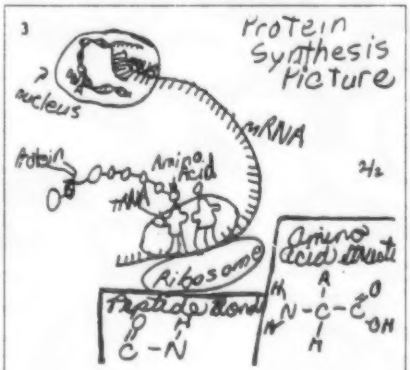
Protein Synthesis
(Transcription and Translation)

Write an explanation or definition in your own words, i.e. paraphrase. (Summarize both steps.)

Transcription – is the first stage of protein synthesis. It consists of a DNA strand that unzips itself. A mRNA molecule attaches itself to the template of the DNA and reads the code. The mRNA moves out of the nucleus and DNA rezips itself. mRNA moves toward a ribosome.

Translation – is the second stage of protein synthesis. A ribosome surrounds the mRNA strip. The tRNA then moves in with anticodons to read the mRNA codons. The tRNA goes out to the cell's cytoplasm and attaches to amino acids. The tRNA comes back to the ribosome and attaches amino acids in order to produce a protein.

Draw or find a figurative representation.



List facts (at least five).

- 20 amino acids.
- mRNA is single stranded.
- tRNA is in a key shape.
- 8 amino acids cannot be produced in the body and must be eaten.
- DNA is double stranded and has a twist to it.
- there are 3 bases in one codon.
- there are 64 possible code combinations with 3 of them being terminator codons.
- terminator codons are ATT, ACT, ATC in DNA series.
- DNA, tRNA, and mRNA all consist of a nitrogenous base and a phosphate group.
- amino acids are linked by a peptide bond.

Create your own questions.

What is the general structure of an amino acid?

How are amino acids joined together?

What is a peptide bond?

Create an analogy.

Protein synthesis is like building a house. You have many people to contract and they all have to do their part. They all have to work toegether to get a job done. If one thing does not work, it causes a slight change in plans for everyone.

Figure 4.14: Student's Concept Overview for protein synthesis

Suggestions

- Model how to employ any concept organizer. For example, students find it difficult to think of what a concept is unlike unless teachers give them examples.
- Concentrate on only one frame until students are familiar with it. Using too many different frames too soon will hinder the development of students' analytical skills.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

9. Laboratory Report Outline

One skill all science teachers want their students to develop is the ability to summarize and analyse laboratory experiences. Unfortunately, students often get caught up in the detail of the report and miss the "big picture."

Using a Laboratory Report Outline helps students organize themselves before a laboratory and thus makes them better able to see the purpose for each step in the laboratory.

Procedure

The Laboratory Report Outline assists student learning throughout the laboratory (refer to example, and for a blank copy, refer to Attachment 4.4 at the end of this chapter).

After the prelaboratory, the teacher distributes the Laboratory Report Outline, then asks students to

1. complete the first page before they begin the laboratory work, including
   - stating the purpose as a question(s)
   - writing down a hypothesis
   - outlining the theory in the prelaboratory section
   - listing apparatus
   - stating the procedure (see example)

The teacher can check students' prelaboratory understanding and provide feedback to help them in their preparations for future laboratories.

During the laboratory, students

2. jot down observations on the second page. Additional tables could be prepared in advance. As students' process skills improve, they can design these tables themselves.

After laboratory clean-up, students

3. discuss with a partner the questions in the conclusions section.
4. write a summary paragraph.
   By checking these paragraphs, the teacher determines what students actually learned. If the summary paragraph is the same as the prelaboratory paragraph, the teacher needs to ask the student probing questions about what they learned.

5. write a formal report based on this Laboratory Report Outline (refer to *Chapter 7: Technical Writing in Science*).

Using these report outlines should become second nature to students.

Suggestions

- If students are having difficulty writing a particular section in a formal report, discuss their outlines with them. Using the outline often helps students clear up problems.
- Reduce extra marking by having students hand in a completed laboratory report outline with only one section completed in formal writing. Also, focus on the requirements for each section, as that section is assigned. Perhaps one time students could concentrate on a polished prelaboratory section and another time write a good conclusions section.
- Do not assign laboratory report outlines to the weakest students only. All students can benefit from organizing before writing.

Example

An example of two students' Laboratory Report Outline for Chemistry is shown in Figure 4.15.

LABORATORY REPORT OUTLINE on Physical and Chemical Properties of Matter (foil)

Course: Chem

Lab#: 2

Name: ____________

Date: Sept. 11

Introduction

Purposes(s): The purpose of this laboratory is to answer the following question(s).

What are the differences between the physical and chemical properties of foil?

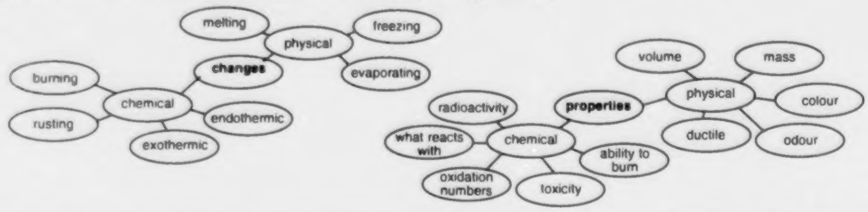
Hypothesis and Rationale:

We predict that the rubbed strips of foil will be more affected by the base and acid because the self-protecting layer is being rubbed off. There will be chemical reactions between the aluminum foil and the liquids.

Background:

This laboratory is about physical and chemical properties of matter (foil)

Background information (in outline or concept map form):

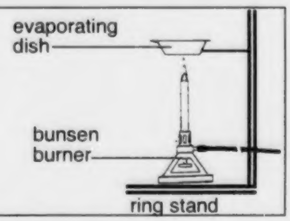


Apparatus:

List (quality and quantity):

- 6 cm x 4 cm piece of aluminum foil
- 5 mL of 6M HCl
- 5 mL of 6M NaOH
- 7-13 mm x 100 mm test tubes
- steel wool
- glass tubing
- rubber stopper
- small beaker
- 8 mL distilled water
- 1 evaporating dish
- 1 bunsen burner
- 3 mL ammonia water

Diagram:



Procedure:

1. Obtain 6 cm x 4 cm piece of foil • Cut into 2 equal pieces • Rub one piece with steel wool • Cut it into 0.5 cm x 4 cm strips
2. Also cut unrubbed foil into 0.5 cm x 4 cm strips
3. a) Pour 5 mL of 6M HCl into two of the 13 mm x 100 mm test tubes
   b) Pour 5 mL of 6M NaOH into the other two test tubes
4. Place one rubbed strip of foil in one test tube of NaOH and on unrubbed strip into the second test tube of NaOH. Record observations.
5. Prepare to collect gas generated in step 6 using glass tubing in a rubber stopper and tubing into a submerged test tube. Use water displacement.
6. Place one rubbed strip of foil in HCl. Catch gas evolved in empty test tube. When all action has stopped, light splint and bring to mouth of tube of gas. Record observations.
7. Place an unrubbed strip of foil in the second tube of HCl. Record observations.
8. Place 5 mL of distilled water in an evaporating dish. Add contents of one HCl test tube to the dish. Evaporate liquid above the burner. Note colour.
9. When coded, add 3 mL distilled water. Stir to dissolve. Pour into clear test tube and add 3 mL of ammonia water. Record observations.

Changes to the original plan:

Laboratory Report Outline: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

General Observations

I) Physical Properties

6.00 cm long
4.00 cm wide
0.14 g mass
shiny silver colour
no odour
does not dissolve in water
good heat conductor
very malleable
non-ductile

II) Chemical Properties

NaOH

Rubbed	Unrubbed
– reaction (bubbles) immediately	– fast bubbling after 0:20 S.
– continued to react	– started slowly then sped up
– aluminum began to break up	– transparent to begin with
– slower bubbles after 2:10 min.	– bubbles rose to surface
– chalky, cloudy translucent mixture	– condensation on inside of tube
– upward moving bubbles	– exothermic

Rubbed	Unrubbed
0:30 – starts to react (bubble)	– 45s starts to bubble
1:00 min – vigorously bubbling – fizzy bubbles	– gradually speeds up
1:30 min – aluminum foil disappears	– reacts slower than rubbed aluminum foil
– turns bluish colour	– foamy around edges
2:00 min – heat produced	2:00 min – foil disappeared
3:00 min – tube full of gas	– still reacting after 10:00 min.
– when splint was lit, popping sound in tube	

Ammonia water	Evaporation:
– transparent	– yellowish-green liquid when HCl and distilled water combined
– strong odour	– residue yellow in colour
– became translucent	
– looked as if starting to crystallize	

Analysis:

The reason for doing this laboratory was to prove that aluminum foil has physical and chemical properties and that it will react with a base and an acid.

We had predicted that the rubbed foil would react better with the base and acid because the protective coating was removed. We also predicted the aluminum foil would react with both the base and the acid.

Our hypotheses were proven correct/incorrect as the rubbed foil reacted more quickly with the HCl and NaOH. The second test also produced a gas, which demonstrates a chemical reaction occurred.

Possible sources of error were some of the air could have seeped into our test tube if the tubing was not right at the top. We could have also heated our evaporating dish too quickly or not enough.

Conclusion:

In summary: Aluminum foil has physical and chemical properties. Physical properties include mass, colour, and width of the aluminum foil. Chemical reactions also took place. When NaOH combined with foil, chemical reactions also took place. When NaOH combined with Al, hydrogen gas and sodium aluminate were produced. Heat was produced because of the breaking and forming of the bonds between the molecules. Another chemical reaction occurred when HCl and Al combined to form hydrogen and aluminum chloride. The chemical properties need to react with another substance before they can be determined, while physical properties can simply be found without reactions occurring.

Figure 4.15: Students' Laboratory Report Outline for chemistry

10. Article Analysis Frames

This frame is designed to replace the traditional written article report. It not only allows the teacher to see what their students learned from reading an article, but it focuses students before and during reading. Sections of the frame are based on a concept organizer, stressing different learning styles.

The Article Analysis Frame is useful and versatile in its application. If it is used by teachers from other disciplines such as social studies and language arts, teaching for transfer is promoted.

Procedure

This frame has two sides:

- *fact based*
- *issue based*

Using the blank copies at the end of this chapter, photocopy the Fact-Based Article Analysis sheet (Attachment 4.6) back to back with the Issue-Based Analysis sheet (Attachment 4.5). Students can then decide if the article they are reading deals with facts or issues and choose the appropriate frame. Students may need guidance in identifying fact-based versus issue-based articles.

Example

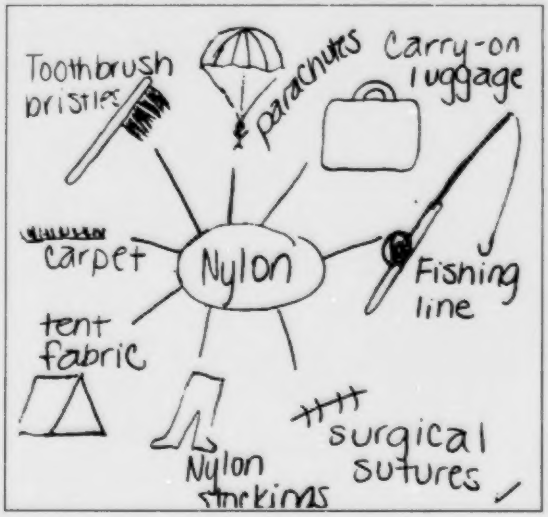
An example of how one student completed a Fact-Based Article Analysis Frame is shown in Figure 4.16.

Fact-Based Article Analysis

Key Concept (written in a sentence):

The introduction of Nylon 50 years ago has totally revolutionized the way we live.

Draw a figurative representation.



What are the scientific facts? List at least five.

1) Polymers are molecular chains of sub-units.
2) Nylon can be heat set to make its yarns coil and stretch much like telephone cords.
3) Chemists can string some of the polymer sub-units together in specific order.
4) Polymers can sometimes be made to fold up into molecular objects.
5) The simple rearrangement of molecules can transform air, water, and coal into Nylon.

Write an article summary or definition in your own words. Do not list facts. Give an overview.

Nylon was the first entirely man-made fibre, and it totally changed industry and everyday life. Nylon was used for many things (luggage, toothburshes, carpet, fishing line, surgical sutures), but perhaps its best known use was in fabrics. The popularity of Nylon stockings led to riots in the 1940s. The strength and sheerness of Nylon made it the ideal choice and was also used in parachute cloth ropes and tent fabric.

Nylon also led to other "unnatural" fibres (Teflon, polyester, spandex) as well as work with recombinant DNA and the biotechnology of today. Work with protein polymers is likely to create new methods of curing disease and to allow them to serve as very small machines.

List your questions (at least two).

1) What are sub-units?
2) What is recombinant DNA?

Explain the technology presented.

Polymer technology was what created Nylon. It involved stringing the sub-units of polymers together in a specific order to make a new substance. Polymer technology led to nano-technology, which is folding up polymers into molecular objects which can serve as pieces of extremely small machines and electronic components. With molecular devices, one could make a microscopic computer.

List at least five key words.

• polymer	• rearrangement
• revolutionized	• man-made
• future	• spin-offs

Relevance to today; this is important or not important because . . .

Nylon is very important today because it has created so many things and made so many changes in our lives. It has provided a far better material for many industries and has allowed the public to reap the benefits of these changes (e.g., no waiting at airports; stronger, sheerer stockings; affordable carpet; etc.). Nylon has also opened up the way for new materials and new technologies such as Teflon, polyester, Spandex, recombinant DNA, biotechnology and nanotechnology. Nanotechnology will surely be a great device in the future.

Figure 4.16: A Student's Fact-Based Article Analysis

Fact-Based Article Analysis: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

11. Note Frame

This frame

- helps organize the weaker student who has trouble following lectures and taking notes
- can be used to keep a student on task by requiring that he/she take notes at the same time as everyone else but on a more manageable level

Procedure

1. To implement the Note Frame strategy, the teacher must prepare two items:
   a) overhead notes, notes on the blackboard, or notes on the computer (as depicted in Figure 4.17 below)
   b) a similar hand-out of framed notes with blanks for key words (refer to Figure 4.17)
2. The teacher then has students complete the frame as the information is presented.

Overhead Notes:

The purposes of the circulatory system are

- to transport needed substances (oxygen, nutrients, hormones, etc.) to all living body cells.
- to remove wastes (carbon dioxide, nitrogenous wastes, etc.) from those cells
- to defend the body
- to maintain homeostasis

Framed Notes:

The purposes of the ____________________ are

- to __________ needed substances (__________, nutrients, ______________, etc.) to all living body cells.
- to remove __________ (carbon dioxide, nitrogenous wastes, etc.) from those __________
- to defend the body
- to maintain ______________________.

Figure 4.17: Note Frames for biology

Note Frames: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Suggestions

- Word process Note Frames so notes can be changed from year to year.
- Point out to the students that when additional comments are written or when diagrams are given, they should also be recorded as additional notes.

Summary

Using maps and frames develops students' thinking. Besides increasing the students' ability to retrieve and organize information, using these strategies "make(s) the thinking visible for both the students and the teacher" (Bellanca and Fogarty, 1992, 10).

References

Bellanca, J., and R. Fogarty. "Cognition in Practice." *If Minds Matter: A Foreword to the Future*. Vol. 2. Eds. A. Costa, J. Bellanca, and R. Fogarty. Palatine, IL: Skylight Publishing, 1992. 3-21.

Berkowitz, S. "Effects of Instruction in Text Organization on Sixth-grade Student's Memory for Expository Reading." *Reading Research Quarterly* 21 (1986): 162-177.

Bloom, B.S., et al. *Taxonomy of Educational Objectives: Handbook 1, Cognitive Domain*. New York, NY: D. McKay, 1956.

The Conference Board of Canada. *Employability Skill Profile*. Ottawa, ON: The Conference Board of Canada, 1993.

Cook, D. *Strategic Learning in the Content Areas*. Madison, WI: Wisconsin Department of Public Instruction, 1993.

Fusco, E., and G. Fountain. "Reflective Teacher, Reflective Learner." *If Minds Matter: A Foreword to the Future*. Vol. 1. Eds. A. Costa, J. Bellanca, and R. Fogarty. Palatine, IL: Skylight Publishing, 1992. 239-255.

Isol, L., and V. Croll. "Story-Mapping Training as a Means of Improving Reading Comprehension." *Learning Disability Quarterly* 10 (1987): 214-229.

Jones, B., A. Palincsar, D. Ogle, and E. Carr. *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas.* Alexandria, VA: Association for Supervision and Curriculum Development, 1987.

Lyman, F., and J. McTighe. "Cueing Thinking in the Classroom:The Promise of Theory-Embedded Tools." *Educational Leadership* 45.7 (1988).

Peresich, M., J. Meadows, and R. Sinatra. "Content Area Cognitive Mapping for Reading and Writing Proficiency." *Journal of Reading* 33.6 (1990): 424-431.

Sizmur, S. "Concept Mapping, Language and Learning in the Classroom." *School Science Review* 76.274 (1994): 120-125.

Tarasoff, M. *Reading Instruction That Makes Sense.* Victoria, BC: Active Learning Institute, 1993.

Attachment 4.1

Concept Relationship Frame

Problem/Solution   Either/Or   Compare/Contrast   Cause/Effect

Make the distinction between:

________________: ________________:

Write a summary statement:

Concept Relationship Frame: Adapted from JoAnne Caldwell, Ph.D. Cardinal Stritch University, Milwaukee, WI. Used with permission.

Attachment 4.2

Concept Frame

Concept

Examples

Characteristics

What is it like?

What is it unlike?

Can you illustrate it?

Definition

Concept Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Attachment 4.3

Concept Overview

Key word or concept.

Draw a figurative representation.

Create your own questions about the concept.

Write an explanation or definition in your own words. You will be paraphrasing.

List facts (at least five).

Create an analogy.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Attachment 4.4

LABORATORY REPORT OUTLINE
on

____

Course: ________________

Lab#: ________________

Name: ________________

Date: ________________

Introduction

Purpose(s): The purpose of this laboratory is to answer the following question(s).

____

Hypothesis and Rationale:

Background:

This laboratory is about ____________________________

Background information (in outline or concept map form):

Apparatus:

List (quality and quantity):

Diagram:

Procedure:

Changes to the original plan:

Attachment 4.4 continued

General Observations

Analysis:

The reason for doing this laboratory was to prove that

We had predicted that

Our hypotheses were proven correct/incorrect as

Possible sources of error were

Conclusion:

In summary,

Laboratory Report Outline: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Attachment 4.5

Issue-Based Article Analysis

When you read the article, did it inform you but not raise any concerns? If so, use the fact-based article analysis sheet. If the article presented a certain point of view about an issue under dispute, use this sheet.

Issue (written as a question).

Write a summary in your own words. (paraphrase)

Draw a figurative representation.

List your questions (at least two).

What is the author's opinion? Give one piece of evidence.

What is your opinion?

Relevance to today; this is important or not important because . . .

Issue-Based Article Analysis: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Attachment 4.6

Fact-Based Article Analysis

When you read the article, did it present a certain point of view about an issue under dispute? If so, use the issue-based article analysis sheet. If the article informed you but did not raise any concerns, use this sheet.

Key concept (written in a sentence).

Draw a figurative representation.

What are the facts? List at least five.

Write an article summary or definition in your own words. Do not list facts. Give an overview.

List your questions (at least two).

List at least five key words.

Relevance to today; this is important or not important because . . .

Fact-Based Article Analysis: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

CHAPTER 5: READING SCIENTIFIC INFORMATION

CHAPTER 5: READING SCIENTIFIC INFORMATION

Students often have problems reading science textbooks because few texts are "user friendly" and teachers rarely take the time to help students learn how to get the maximum benefit from them.

In this information age, students require skills to understand a wide variety of materials. Scientific journals, newspaper articles, computer printouts, field notes, prescriptions, graphs, and tables are now all part of the information base (Cook, 1993). The student must not only think about how to access information, he/she must be selective—a difficult task in an information overload world.

Reading only provides knowledge and sparks interest if content is understood.

Reading only provides knowledge and sparks interest if content is understood. Concepts can only be understood and later recalled and applied if they are deeply processed. By choosing appropriate teaching strategies and by modelling reading techniques, teachers can help students acquire the skills to access, read, and process scientific and technical information.

This chapter first reviews

- the steps involved in developing good reading skills
- questions that good readers ask
- what makes a science text easy to read

Then it presents several strategies in detail—strategies that help students acquire the skills they need to comprehend science texts and scientific information accessed from multimedia sources.

Developing Good Reading Skills

Jones et al. (1987) have identified the steps good readers take as they read.

1. They begin by *skimming* text features. In particular, they read the title, subtitles, graphics captions, introductions, and summaries.
2. They *analyse* the material on two levels:

Level 1	They consider what is recognizable about the content. When given a passage from a general science textbook on chemical changes, they can remember, for example, that burning is a chemical change.

Level 2 They find out what is recognizable about the format and text structure. Is the material written, for example, in an expository format using a compare/contrast structure or some other structure?

The advantage of approaching reading by skimming and analysis is that readers come up with a framework for new information. In other words, prior knowledge has been activated.

3. They *form an hypothesis* about the author's intent and the meaning of the reading.

4. They *read for detail*. As they read, they realize how new information fits in with the text structure and with their prior knowledge. They pose questions to themselves and evaluate how accurate their hypotheses were.

All along, the readers are interacting with the text material.

Questions Good Readers Ask

What do students understand about the material they read? It appears they comprehend on three levels:

Level 1 This level requires recalling and remembering facts by analysing, organizing, and categorizing material. This is *reading on the lines*—understanding is literal.

Level 2 This level expects students to see relationships between ideas and elaborate on them by creating examples or paraphrasing. This is *reading between the lines*—ideas must be interpreted.

Level 3 This level involves transferring ideas, i.e., interrelating concepts, creating analogies, and solving problems. This is *reading beyond the lines*—here information is applied.

Three types of questions parallel these three levels of comprehension.

Three types of questions parallel these three levels of comprehension. Teachers can guide students to each level by exposing and modelling different levels of questions. By using the Question-Answer Relationships (QAR) and Re Quest strategies outlined in this chapter, students can begin to identify and create higher-level questions on their own.

As students become proficient at developing better questions, class discussions will be more interesting and productive. The Reciprocal Teaching strategy outlined in this chapter promotes this interaction. When students develop good questioning skills, the teacher is creating a more learner-centred classroom.

Also, by using good questioning skills, students will be able to analyse a text for its readability and quality of information.

Qualities of a Considerate Text

What makes an article easy to read or considerate?*

A considerate text is easy to follow because it is well written and well organized. The author has thought about the material and its content and has chosen a suitable genre or category and text structure. Once the author chooses a text structure, he or she does not switch structures without preparing the reader.

Most science textbooks are written as expository texts, meaning they explain something. Writing in these texts usually oscillates among three basic categories (refer to Figure 5.1):

- having a main idea and supporting details
- describing a sequence
- containing two or more important elements or ideas

An author may decide to shift between text structures within a category. For example, in an article about substance abuse, the author might implement a cause/effect structure when describing the effects of drugs, switch to a compare/contrast structure to explain the differences between drugs, and then use a problem/solution structure when discussing solutions to drug abuse problems (Cook, 1993).

Notice how the cue words listed in Figure 5.1 can assist a reader in imposing a framework or structure to the reading. For example, the word "likewise" tells the reader it is a compare/contrast structure.

* The term *considerate* was first coined by Anderson and Armbuster to help teachers look beyond the basic reading level of a text (Jones et al., 1987).

Category	Text Structure	Cue Words	Frame Questions
Main Ideas/Supporting Details	a. description	further, also, moreover, too	What is it? Where is it found?
	b. proposition/ support	above all, indicate, suggest, of course	What is the thesis? How is it supported?
	c. argumentation for conclusion	in conclusion, therefore, if, for these reasons	What premises support the conclusion?
	d. concept/ definition	specifically, as, e.g., for instance, like	How does it work? What does it do?
Sequence	a. sequence	finally, then, now, to begin with, before	How did it begin? List the steps.
	b. goal/action/ outcome	if, providing, although, whenever, unless	What is the goal? Identify the outcome.
Two or More Elements	a. compare/ contrast	likewise, while, yet, regardless, whereas	How are they alike? How do they differ?
	b. problem/ solution	because, instead of, rather than, therefore	What is the problem? What is causing it?
	c. cause/ effect	since, then, so that, consequently, if . . . then	What is the result? What factors caused this to occur?
	d. interaction	between, upon	How do they act and react?

Figure 5.1: Common text structures (Cook, 1993)

Once students can pinpoint the text structure, they can find the category and identify the frame questions. Questions like the ones listed in Figure 5.1 assist students in analysing what is important and organizing new information. This process guides readers as they begin to link the ideas presented in the text to their prior knowledge. Several strategies can be used "during reading" to assist the student in interpreting the text. See Graphic Outlines (page 5.13) and Reading for Meaning (page 5.15).

Strategic Lesson Planning

Students will learn content better if teachers split reading exercises into three sections:

- pre-reading
- during-reading
- post-reading

For example, students will read more successfully if they are pre-taught the difficult vocabulary (*pre-reading*). They will understand better if they are asked to first paraphrase what has been read (*during-reading*) and then complete an Article Analysis Frame (*post-reading*). Teachers can apply this same three-phase learning process when students view videotapes and/or listen to audiotapes.

A number of strategies for each of these lesson stages are described in detail in the second half of this chapter.

Pre-Reading Strategies

Pre-reading strategies help prepare students for learning by

- establishing a purpose or focus for the reading
- activating students' prior knowledge so that connections with new information can be made
- emphasizing new terms and vocabulary
- considering the qualities of the textbook

During-Reading Strategies

Soon after students finish a reading, teachers can implement during-reading strategies to help students think about what they just read. These strategies are effective because they require students to interact with the material and each other as they are reading. Reading is no longer passive.

These during-reading strategies are listed in Figure 5.2 below. The **bolded** strategies are explained in detail in this chapter.

Purpose	Strategy	Chapter outlined in
To promote collaboration	1. Listen—Think—Pair—Share **2. Reciprocal Teaching**	Chapter 2, p.6 This chapter
To recognize text structure	**3. Graphic Outlines** **4. Reading for Meaning**	This chapter This chapter
To develop better questions	**5. Re Quest** **6. Question – Answer – Relationships (QAR)**	This chapter This chapter
To promote more interaction with the material as students read silently	**7. Note Taking** A variety of strategies	This chapter Chapter 6: Writing to Learn Science
To develop graphic and visual literacy	**8. Visuals: Text and Students'**	This chapter

Figure 5.2: During-Reading strategies

Figure 5.2: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Post-Reading Strategies

Post-reading strategies are implemented after the students have completed a reading.

These strategies are designed to teach students how to apply content by

- increasing comprehension and recall
- connecting details to the big picture
- making new connections
- applying ideas
- transferring knowledge

These strategies may be used for post-reading or whenever content is learned. For this reason, they are outlined in detail elsewhere in this handbook, as listed in Figure 5.3 below.

Purpose	Strategy	Chapter outlined in
To use writing to extend learning	A variety of strategies	Chapter 6: Writing to Learn Science
To promote collaboration	Listen—Think—Pair—Share	Page 2.6
To organize and analyse concepts	A variety of of strategies	Chapter 4: Developing Scientific Concepts Using Graphic Displays (Maps and Frames)

Figure 5.3: Post-Reading Strategies

Getting Started

As teachers, you are encouraged to start small. Before beginning, overview the reading strategies provided and look for what seems comfortable to teach and try it. Use it repeatedly until students can apply it automatically. Then, introduce another strategy or a variation of it, and so on. Students will be more successful with a particular reading strategy if it is modelled, used frequently, applied to a variety of topics, and monitored. Over a period of time, these teaching techniques will feel easier to implement and to adopt into the regular classroom instruction.

Figure 5.3: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Pre-Reading Strategies in Detail

1. Textbook Survey

The purpose of this strategy is not to assess the text but rather to become familiar with its components.

Procedure

Teachers should begin by having the students learn more about how the textbook and chapters are organized and written.

- Is the book well organized?
  - Do the simple topics precede the complex ones?
  - Does the textbook have a glossary, table of contents, an index, or appendices? Are they complete?
- Within each chapter, check for the following:
  - Are key words outlined?
  - Does the introduction tell you what the chapter is about?
  - Are explanations simple and clear?
  - Is the vocabulary at an appropriate level?
  - Does the text provide relevant information or too many "nice to know" details?
  - Are there interest sections that relate scientific processes to people's concerns?
  - Are suggestions for co-operative learning and journal entries offered?

A specific form could be designed to survey each text based on these and additional questions.

Suggestion

Before you buy a new textbook, Cook suggest you analyse a copy to see if it is considerate. She provides a textbook assessment form for that purpose in *Strategic Learning in the Content Areas* (1993, 36–37) (refer to References at the end of this chapter). This survey can also be found in *Assessing Readability: The Checklist Approach* (Irwin and Davis, 1980, 129–130).

During-Reading Strategies in Detail

2. Reciprocal Teaching

Often, teachers find students do not have the skills to lead discussions effectively.

This during-reading strategy

- teaches discussion skills
- focuses on four thinking skills:
  - summarizing
  - generating questions
  - clarifying
  - predicting

The strategy is reciprocal because after the teacher models it, each student has a chance to lead the discussion.

Procedure

This strategy involves whole-class participation.

1. The teacher and students silently read the text passage on their own.
2. The teacher takes turns with the students leading the discussion.

   To lead it, each leader should be asked to demonstrate these four skills:

   - *summarizing* (restating what was read)
   - *questioning* (other students about the passage)
   - *clarifying* (indicating what was difficult to read and asking for input from the others)
   - *predicting* (what might follow in the text)
3. Everyone (including the teacher) comments, answers a question, or adds input at any point in the discussion.

Suggestions

By your modelling the discussion-leader role first and demonstrating the four thinking skills, students will be better prepared to assume this role later. It would be most beneficial if, at first, students practised each thinking skill separately.

Reciprocal Teaching: From "Teaching and Practicing Thinking Skills to Promote Comprehension in the Context of Group Problem Solving" by A.S. Palincsar and A.L. Brown, Jan./Feb. 1988, *Remedial and Special Education* 9.1: 53–59. Copyright © 1988 by PRO-ED, Inc. Adapted and reprinted by permission.

3. Graphic Outlines

Because of the variety of text structures, students may have difficulty recognizing the structure of a reading. By implementing graphic outlines, teachers can help students

- analyse text structures
- identify the important material

Procedure

A variety of concept strategies using maps and graphic outlines are described in *Chapter 4: Developing Scientific Concepts Using Graphic Displays*. For example, the Compare and Contrast strategy works well for text structures with two events.

Suggestions

Graphic outlines can be applied throughout a lesson:

- *before reading* or problem solving—as an advance organizer
- *during reading* or problem solving—to help students focus on what is important
- *after a lesson*—to assist students in summarizing, sequencing, and integrating information (Jones et. al. 1987, 37)

After learning how to use graphic outlines, students could be assigned a particular reading and asked to complete an outline for homework.

Good readers develop and internalize graphic outlines for different text structures. As soon as they see certain cue words, they recall a particular graphic outline. As teachers you can intervene to improve reading comprehension by introducing students to different text structures, using graphic outline "think sheets*." If students are given frequent opportunities to use them, most students will internalize these structures. Others may need a graphic outline to help them each time.

Example

Students were given the graphic outline think sheet and asked to fill it in based on a text reading about aliphatic hydrocarbons (refer to Figure 5.4). This think sheet helped students organize their thoughts while recognizing a particular text structure.

* Hard copy graphic outlines, such as Concept Organizer, Word Cycle, and Three Point Approach, (see Chapter 4: Developing Scientific Concepts Using Graphic Displays) are often called "think sheets." They help students frame their thoughts.

Aliphatic Hydrocarbons
(Text notes)

Alkanes

A chain compound in which all carbon-carbon bonds are single bonds is called an Alkane or saturated hydrocarbon

1st 4 members of Alkane (paraffin) series: methane, CH_4; ethane, C_2H_6; propane, C_3H_8; butane, C_4H_{10}. Characteristic of this series is the words end in -ane.

The general formula for the homologous series of the Alkanes is C_nH_{2n+2}. (n=# of carbon atoms in the compound.) Methane is the simplest alkane.

If 1 hydrogen atom, along with its electron, is removed from a hydrocarbon molecule, a radical is left. Radicals are named by changing the -ane ending to -yl. example methane → methyl.

General trend → as molecular mass of the cmpnd ↑, the boiling point ↑. Alkanes are soluble in nonpolar solvents.

Alkenes

Unsaturated hydrocarbons with double bonds between carbon atoms are Alkenes or olefins. Alkenes are another homologous series of hydrocarbons.

The general formula for the homologous series of the Alkenes is C_nH_{2n}. 1st 5 members → ethene C_2H_4; propene C_3H_6; butene C_4H_8; pentene C_5H_{10}; hexene C_6H_{12}

Double bonds are stronger than single bonds (not twice as strong) and also more reactive. Alkenes are unsaturated hydrocarbons containing multiple bonds.

Cmpnds are named according to the longest chain with a dble bond. The lowest possible position # is assigned to the first dble-bonded carbon atom.

Alkene isomers differ in the formation of their double bonds. Dble bonds are also found in cyclic compounds – DIENE = 2 dble-bonds.

Alkynes

Alkynes → Homologous series of hydrocarbons consisting of molecules containing *triple bonds.*

The general formula for the homologous series of the Alkynes is C_nH_{2n-2}.
Important raw materials for industries producing synthetic materials (fibres, plastics)

Alkynes named like Alkenes but end in -yne. Chemically Alkynes are very reactive. Acetylene (common name for ethyne) is commercially important.

1st three members of the alkyne family and their formulas are: ethyne C_2H_2; propyne C_3H_4; butyne C_4H_6.

The lowest possible position number is assigned to the first triple-bonded carbon atom.

Figure 5.4: Text-reading notes are organized on a graphic outline sheet

4. Reading for Meaning

Students need to learn to recognize the text structure category and the benefits of a Category Concept Map.

In this during-reading strategy, students

- identify the main idea and supporting details in a text
- build a Concept Map to illustrate the ideas and details (see Figure 5.5)

Procedure

Initially, the teacher models this strategy to the class with a sample article. It is best to use a short article with one text structure (main idea and supporting details) and a title. It is important to indicate to the students that the article contains only one type of text structure.

After reading the article, students

1. build a Concept Map depicting the main idea and supporting details in the article

Using the Concept Map to take notes, students

2. survey the article by reading the title and first and last paragraphs
3. identify the main idea and place the main idea in a circle in the centre of the page
4. read the remainder of the article, searching for at least four supporting details
5. list each supporting detail in a separate circle off of the main idea and connecting the two with a line
6. state clearly the connection on the line

   The teacher can assist students by suggesting they incorporate into their sentences words like the following: if … then, because, is important because, and so on.

   Note: The teacher should model this step. Students often begin by listing four new words from the text rather than writing complete thoughts to explain connections between the supporting detail and the main idea.

Reading for Meaning: Adapted from Burkle, C., and D. Marshall. *hm Study Skills Program: Level 1*. Copyright 1989 by NASSP. Used with permission. For more information concerning NASSP services and/or programs, please contact NASSP at (703) 860-0200.

7. check their own work to see if connections make sense and the entire article has been interpreted and represented by the map

Variation

Students can put their Concept Maps on poster paper and present them to the class.

Suggestions

- Give the students continuous feedback, both formative and summative.
- Teach this strategy before the Note Taking strategy (this chapter). Students will be able to do the latter strategy once they've identified the main idea and supporting details.
- To help students practise how to identify supporting details and connect them to the main idea, try the Listen—Think—Pair—Share (page 2.6). With this approach, students will have to explain their maps to their partners—reinforcing concepts.
- For more information on the Concept Map strategy, refer to *Chapter 2: Tapping into Prior Knowledge* and *Chapter 4: Developing Scientific Concepts Using Graphic Displays.*

Example

Figure 5.5: Category Concept Map for gene therapy

Evaluation

Once students have strengthened their reading skills and are adept at creating Concept Maps, students can be credited for how well they connected ideas (refer to Figure 5.6).

Reading and Listening for Meaning - Concept Map Evaluation

Name: ______________________________ Date: __________________

Article/Passage mapped:

Format is correct (main idea in centre, at least four supporting details)	/2
Main idea is correctly identified and clearly stated	/2
Supporting details are accurate (information is correct)	/3
Details support main idea	/3
Total	/10

Figure 5.6: Concept Map evaluation.

The Concept Map evaluation scheme above can be enhanced by developing a rubric* based on similar criteria. Three to five levels of performance can be described clearly for each characteristic. Important information is thus provided to teachers, students, and others.

* **Rubric** (definition): A fixed scale and specific set of criteria that describe what performance should look like at each point on the scale. Usually a rubric has between three to five levels.

5. Re Quest

This during-reading strategy assists students in

- identifying question types:
  - on the lines
  - between the lines
  - beyond the lines (Brownlie and Close, 1992)
- interacting with the text by asking questions

The quality of questions is also examined.

Procedure

Initially, it is best if the teacher models the question types and then asks students to try and identify them. As the class becomes more proficient, students can try to identify question types in smaller groups.

The steps are as follows:

1. The teacher and students read the text passage to themselves. After reading, all close their book.
2. Students ask questions about the passage.
3. The teacher clarifies points, helps make connections, and models good questions (on, between, and beyond the lines—see example below).
4. Everyone reads more text, and steps 2, 3, and 4 are repeated until several passages have been analysed in this manner.
5. The teacher then has the students make predictions about what might follow in the reading.
6. Students read on and check their predictions.
7. The teacher follows up with a class discussion, talking about what they learned.

Suggestion

You can often blend this strategy with Reciprocal Teaching (this chapter).

Re Quest: Adapted from Manzo, Tony V. "The ReQuest Procedure." *Journal of Reading* (Nov. 1969): 123–126. Used by permission of International Reading Association.

Example

The following passage was taken from *Nelson Biology* (Ritter et al., 1993, 646).

Oncogenes: Gene Regulation and Cancer

> Cancer is characterized by uncontrolled cell division. Cancer cells are often described as cells that are "too alive." But what causes normal cells to become cancerous? Two lines of evidence indicate that cancer results from changes in the genetic code. First, cancer cells often display nitrogen base substitution, or the movement of genetic material from one part of the chromosome to another. A second factor that supports the idea that cancer arises because of alterations of DNA is the fact that many known mutagens are also known to cause cancer. X rays, ultraviolet radiation, and mutagenic chemicals can also induce cancer.

The following questions fit with the passage.

On the lines

- What types of mutagens cause cancer?
- What is nitrogen base substitution?

Between the lines

- What is meant by a cancer cell being "too alive"?

Beyond the lines

- How could altering the genetic code cause uncontrolled cell division?

6. Question-Answer Relationships (QAR)

In this during-reading strategy, students must identify the type of question they are being asked (Q), answer it (A), and explain what relationship the answer has to it (R). This is a useful questioning strategy for content-area texts.

Procedure

The steps are as follows:

1. The teacher explains the four Question-Answer Relationships (QAR) (McIntosh and Draper, 1995):

- *Right There*—answers are either in the same passage or on the same page
- *Think and Search*—students must look elsewhere in the book for the answers
- *Author and Me*—students construct QARs from the information presented in the text and from prior knowledge
- *On My Own*—students answer QARs without looking at the book

Once students recognize the question types, they will be able to discover whether they can find the answer in the book or not.

2. The teacher demonstrates the different question/answer/relationships (QAR) using examples from science texts.

3. Students practise with the textbook, finding question-answer relationships and identifying what type they are. Worksheets can be developed to help students identify QARs.

Suggestion

If you are considering using this strategy, you may discover a variety of resources that list QAR examples. Before using this strategy, examine these resources for applications to the science textbooks being used.

QAR: Adapted from Raphael, Taffy E. "Teaching Question Answer Relationships, Revisited." *The Reading Teacher* 39.6 (Feb. 1986): 516–522. Used by permission of International Reading Association.

7. Note Taking

This strategy will teach students how to take notes by

- mapping
- outlining

Procedure

1. The teacher puts key words on the board.
2. The teacher breaks the reading into manageable chunks or stops the lecture every ten minutes.

Then, students

3. look for clues for Note Taking (key words on the board, indication of type of text structure, etc.)
4. decide how they will take notes: *outlining* or *mapping* (refer to Figure 5.7)
5. record the main ideas and supporting details in the proper format, as students read or listen. The teacher may want to go around and check whether students are correctly identifying the main idea and supporting details.

As students take notes, the teacher also reminds students to be brief (as if they were writing a telegram).

Suggestions

- It is vital that students understand what makes one a good reader and a good listener. Students should first be taught active listening skills and Reading for Meaning skills (this chapter). Once students can put the main idea and supporting details in Concept Map form, it will be easier for them to develop the outline form (refer to Figure 5.7).

- Remind students of Note Taking strategy alternatives at the beginning of each class (outlining or mapping), and let them choose the one they prefer.

Note Taking: Adapted from Burkle, C., and D. Marshall. hm Study Skills Program: Level 1. Copyright 1989 by NASSP. Used with permission.
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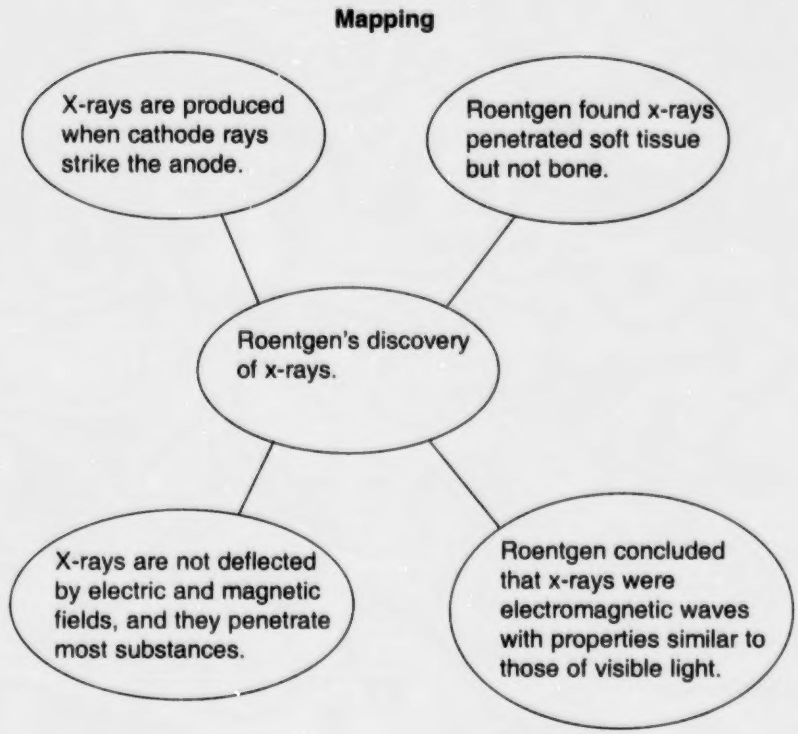
Example



Outlining

I. Roentgen's discovery of x-rays:

A. X-rays are produced when cathode rays strike the anode.

B. X-rays are not deflected by electric and magnetic fields, and they penetrate most substances.

C. Roentgen concluded x-rays were electromagnetic waves with properties similar to those of visible light.

D. Roentgen found x-rays penetrated soft tissue but not bone.

Figure 5.7: Two Note Taking strategies: Concept Mapping and Outlining (based on a Modern Physics unit)

8. Visuals: Text and Students'

This strategy guides students in developing graphic or visual literacy.

Students will be able to learn this skill by

- using *text* visuals
- generating their *own* visuals

Procedure

Text Visuals

To analyse an illustration,

1. the teacher formulates study questions that can help students identify specific information in the visual (do not make the answers too obvious)
2. students evaluate the diagram based on how well it represents what was read in the text
3. students compare related visuals, indicating which represents the information best and how visuals are connected
4. students critique the visual, suggesting improvements and developing criteria to analyse illustrations

Students' Visuals

Students take the information they read and create their own visual (illustration, chart, graph, etc.) using criteria they have developed.

They can draw

- a picture of what they think is the most important event in the text
- a Concept Map of what they have read

Text Visuals: Adapted from Rakes, G., T. Rakes, and L. Smith. "Using Visuals to Enhance Secondary Students' Reading Comprehension of Expository Texts." *Journal of Adolescent & Adult Literacy* 39.1 (Sept. 1995). Used by permission of International Reading Association.

Summary

Science teachers cannot assume that students learn from textbooks, videotapes, and audiotapes simply because the material is age-appropriate. Also, students do not necessarily understand what they're reading, viewing, or hearing. Students must use interactive and collaborative strategies to understand and make sense of the content. In so doing, science teachers can engage students as they read, see, or hear scientific information and concepts. This provides opportunities for teachers to recognize students' misconceptions and also contribute to their learning in many other areas.

References

Berkowitz, S. "Effects of Instruction in Text Organization on Sixth-Grade Students' Memory for Expository Reading." *Reading Research Quarterly* 21.2 (1986).

Brownlie, F., and S. Close. *Beyond Chalk and Talk.* Markham, ON: Pembroke, 1992.

Burkle, C., and D. Marshall. *Home Study Skills Program: Level 1.* Teacher's Guide. Reston,VA: NASSP and NAESP, 1989.

Cook, D. *Strategic Learning in the Content Areas.* Madison, WI: Wisconsin Department of Public Instruction, 1993.

Idol, L., and V. Croll. "Story-Mapping Training as a Means of Improving Reading Comprehension." *Learning Disability Quarterly* 10 (1987).

Irwin, J.W., and C.A. Davis. "Assessing Readability: The Checklist Approach." *Journal of Reading* 24 (1980): 129-130.

Jones, B., A. Palincsar, D. Ogle, and E. Carr. *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas.* Alexandria, VA: Association for Supervision and Curriculum Development (1987).

Manitoba Education and Training. *1992 Reading Assessment Recommendations Grades 4, 8, 11: Reading Final Report, English Language Schools,* Winnipeg, MB: Manitoba Education and Training, 1992.

Manzo, Tony V. "The Re Quest Procedure." *Journal of Reading* 28.6 (1969): 498-503.

McIntosh, M., and R.J. Draper, "Applying the Question-Answer Relationship Strategy in Mathematics." *Journal of Adolescent and Adult Literacy* 39.2 (1995).

Palincsar, A., and A. Brown. "Teaching and Practising Thinking Skills to Promote Comprehension in the Context of Group Problem Solving." *Remedial and Special Education* 9.1 (1988).

Rakes, G., T. Rakes, and L. Smith, "Using Visuals to Enhance Secondary Students' Reading Comprehension of Expository Texts." *Journal of Adolescent and Adult Literacy* 39.1 (1995).

Ritter, B., R. Coombs, R. Drysdale, G. Gardner, and D. Lunn. *Nelson Biology*. Scarborough, ON: Nelson Canada, 1993. 646.

Smith, P., and G. Tompkins, "Structured Notetaking: A New Strategy for Content Area Readers." *Journal of Reading* 32.1 (1988).

Whitin, D., and S. Wilde. *Read Any Good Math Lately?* Portsmouth, NH: Heinemann, 1992.

CHAPTER 6: WRITING TO LEARN SCIENCE

CHAPTER 6: WRITING TO LEARN SCIENCE

Students do not construct and learn science concepts and relationships effectively through passive absorption. Students learn best when they can link new ideas and skills to prior knowledge through active engagement in listening, speaking, reading, writing, and thinking.

The process of trying to communicate what they know, understand, and can do leads students to examine their understanding more deeply and completely.

The process of trying to communicate what they know, understand, and can do leads students to examine their understanding more deeply and completely. By using formal and informal writing-to-learn strategies, students begin to think their way through a new concept, making sense of the whirlpool of mental associations, bits of information, half-formed questions, and feelings. These strategies also offer opportunities for teachers to gain insight into the understandings of students and thereby allow them to address undeveloped conceptions, unanswered questions, and misunderstandings.

Implementing writing-to-learn strategies through the use of Science Journals and Portfolios, as presented in this chapter, will help students consolidate their learning in a way that allows them to retain and apply it. The Science Journal contains reflective, informal writing along with sketches, diagrams, charts, quotes, and/or references. Science Portfolios consist of more polished students works.

The Science Journal

Learning Logs and Reflective Writing

Students can construct new science concepts and integrate them into their existing knowledge framework. They are more likely to do this if they relate science to their own lives and apply their science in meaningful contexts. By writing informally about science, science issues, and science applications, students are given the opportunity to make sense of the ideas introduced in class and identify which things they understand and which things they still have questions about. They are also given the freedom to extend and apply these explanations and ideas to contexts and situations that make personal sense to them.

To assist students in this reflective writing process, Science Journal and Science Portfolio strategies are outlined in the following section. These strategies should help increase the depth and longevity of science learning.

Science Journal Strategies

Science Journal strategies include

1. **Free Writing**
2. **Focused Free Writing**
    a. Summarizing a Concept (During Class)
    b. Lesson Response
    c. Clustering
    d. Brainstorming
3. **Problem Solving in Writing—Process Notes**
4. **Divided Notebook**
5. **Reading Response Journal**

These strategies require a variety of thinking skills:

- In the Free Writing and Focused Free Writing strategies, the questions initially asked of the students may only be at the knowledge and comprehension levels. Student free writing can be brought to more sophisticated levels in time as students become more aware of their own writing processes.
- Process Writing and Divided Notebook generally demand more analysis and evaluative skills.

1. Free Writing

Spontaneous free writing is simply non-stop writing for a short period, say, five to ten minutes. The writer suspends critical judgment of the sentence structure, word choice, or tone.

By having students spontaneously express their ideas at crucial learning times, they tap into their thinking processes and construct, connect, clarify, and consolidate meaning.

Procedure

Start class with a three-minute free write. This helps settle the class down. Assigning a specific topic focuses students on the lesson.

Ask students to apply their spontaneous, reflective writing to

- respond to a specific question (Focused Free Write)
- reflect on what they have just learned
- recall the process they used to solve a problem
- generate questions
- explore personal associations
- brainstorm applications
- sort out their opinion on an issue

Free writing can also be used for other writing-to-learn purposes in science.

Suggestions

Some students may not be accustomed to writing in science courses or may experience writer's block. To help them overcome their inhibitions, explain that they can record their thoughts and feelings in any manner they wish.

To help them get started, consider

- beginning with feeling questions, as these are less threatening
- allotting specific class time for writing
- frequently responding in writing to select journal entries

To help students understand what is expected,

- model the process on the board, overhead projector, or computer
- share with the class models of other students' reflective writing

- explicitly encourage the students: point out unique insights, questions, and connections they can uncover through this spontaneous writing process

As students try to construct their understanding well enough to communicate it in writing, they are challenged to clarify their ideas. This process is also important in helping students become reflective learners.

2. Focused Free Writing

Sometimes teachers want students to write about a specific topic or stretch their thinking in new directions. For these reasons, consider trying Focused Free Writing activities for students' science journals.

The Focused Free Writing strategies outlined below are

a. Summarizing a Concept (During Class)

b. Lesson Response

c. Clustering

d. Brainstorming

a. Summarizing a Concept (During Class)

While teaching a concept, stop occasionally (at about 10-minute intervals) and ask students to summarize what they have seen, heard, or experienced. Focused free writes help students focus on the concept being taught.

Procedure

While "teaching" a concept, say something like,

- "Okay everybody, without saying a word to your neighbour, asking a single question, or stopping long to think, write an explanation of concept X as you understand it so far."
- "When you write,
  - use your own words
  - make it clear so that someone in this class could read and understand it"

Walk around the room while students write, glance at their work, and determine who understands the concept and who does not. More importantly, students, too, will quickly realize how comfortable they are with the new learning.

Variations

Have students *pair* and *share* their work, exchanging their "explanations" with a partner. Ask students to respond orally or in writing after the exchange, answering these kinds of questions:

- Did it work?
- Was it clear?
- Was it accurate?

Have selected students communicate their written summaries to the class. Give honest praise to promote future spontaneous writing attempts.

Suggestions

- Have students pretend they are writing an explanation for a younger sibling, a junior high student, or some other audience.
- Have students attempt to evaluate a concept by giving it some action (i.e., they would describe the concept through a physical example).

b. Lesson Response

Teacher as Audience—After presenting a particular concept/skill, the teacher asks students to write a brief response about what they are learning. Students' responses should be simple and spontaneous, similar to a letter they might write to a friend.

Procedure

- For students who do not know what to write, provide the following prompts:
  - What did you find easiest to learn?
  - What did you already know, or what had you figured out on your own?
  - What is still confusing to you?
  - What did you learn that was new?
  - What did you find really interesting?
  - How do you feel right now about what we're doing?
  - What did you find meaningful to your own life? How does it relate?
  - Does what you're learning now relate to another subject area? What's the connection?

- Do you have any questions (general or specific; related to the material or not) that need to be addressed?

(Note: Some teachers just write these questions on a chart and post it somewhere in the room for quick reference.)

- Lesson responses also work well when the class is discussing a science-technology-society-environment issue. Stop at certain points, especially when the discussion gets particularly heated. Some students need more thinking time before offering their opinions. At these points, ask students to write spontaneously about what
  - they are thinking
  - points they agree/disagree with
  - real-world examples they can think of

- Another type of lesson response is to have students write about an issue from a totally different perspective. For example, in the midst of a discussion on deforestation of Vancouver Island, ask students to assume the role of a representative from MacMillan-Bloedel Pulp and Paper Company. Assume the representative has been listening to the class remarks so far and is going to spontaneously write about his or her thoughts and feelings regarding the issue at hand.

Suggestions

Most importantly, encourage open-ended writing. Students should not be answering a list of questions. Elicit their honest responses; find out what they are learning and why they are having difficulty. It is as much a chance for students to discover their own links with past experiences and prior knowledge as it is for teachers to gain a sense of how well students are processing new information.

Peers as Audience—Students write personal response summaries to a lecture or text reading and exchange this summary with a partner, who writes a response back. In such an exercise, many honest questions emerge—questions that students might not feel comfortable asking the teacher. Students often discover they share associations, difficulties, and thought processes when they work with their peers. Peer responses save time over spontaneous writing.

c. Clustering (also called Mind Mapping, Networking, and Webbing)

This strategy appeals to students who prefer mapping out their thoughts, rather than writing sentences. This method effectively demonstrates the hierarchy of thoughts students store in their minds.

Clustering is explored in more detail in *Chapter 4: Developing Scientific Concepts Using Graphic Displays.*

Procedure

For Clusters or Webs, students

1. jot down the key word or concept in the centre of a page
2. write related words around it
3. draw lines between and write connections to the words

d. Brainstorming

By brainstorming, students may be able to generate more Focused Free Write ideas.

Procedure

The following brainstorming guidelines may help students focus their writing.

- Vary individual and group brainstorming activities.
- Quantity, not quality, is the key to brainstorming. Suspend judgement of students' ideas as they create and develop new ideas. Have competitions for the most ideas, and celebrate unique offerings.
- Ask students to spontaneously write predictions based on their prior knowledge about experimental outcomes, chemical reactions, or behaviour of objects.
- Brainstorm how the new concept applies to their daily lives and the world around them.

Sample Brainstorming Activities

Brainstorming ideas are suggested below.

- The teacher asks, "In your experience, how many things can you think of where chemical changes occur in aqueous solutions?" Students choose one and explain in writing what they think the chemical change is.

- The teacher divides the class into groups and asks each group to list three solutions encountered in daily life. Students work with partners to define the characteristics of these solutions, relating what they already know about the properties of electrolytes, non–electrolytes, acids, and bases. Students present their findings to the class.

- The teacher asks students to compare something new to something they are familiar with, and explain the comparison (called writing similes). For example,

  A cell is like a ________________ *because* ________________.

  (A cell is like a factory because it takes in raw materials, produces new materials, and gets rid of wastes.)

- The teacher asks students, "Imagine you are observing the outcome of a lab experiment you are about to perform. Describe in detail what you see."

- For an abstract concept, process, or set of relationships, the teacher asks students to imagine its colour, its shape, the place it is in, and the ecological system it could be thought to be part of. (What depends on it? On what does it depend? What does it eat? What eats it?)

- The teacher asks students to assess their own learning based on what they've demonstrated on tests by writing specific learning goals for themselves. (The teacher helps students design learning strategies to achieve their goals.)

- The teacher places students in groups and asks them to evaluate themselves and their group on one or two particular group skills. The following list of group skills may be used:
  - asking questions
  - asking for clarification
  - checking for others' understanding
  - elaborating on each other's ideas
  - following directions
  - getting the group back to work
  - keeping track of time
  - listening actively
  - sharing information and ideas
  - staying on task

- summarizing for understanding, that is, paraphrasing

- Students comment on a specific teaching strategy or assignment that they like or dislike.

3. Problem Solving in Writing—Process Notes

In this strategy, students assess the process they used in a problem-solving situation.

The advantage of process writing is that it requires students to be active learners—to find new approaches to problems, to develop new algorithms, and, in general, to spend more time on a task (Kenyon, 1989, 74).

Procedure

In this strategy, the teacher asks students to

1. immediately after finishing it, describe the process they went through in solving a specific problem (even if they got stuck and did not solve the problem)
2. with a partner, or in a small group, compare this to how others solved the problem
3. re-evaluate the efficiency of their own problem-solving process; that is, How would they improve their approach to a similar problem next time?

Variation

In step 2, instead of pairing, the teacher leads the class through a suggested method of problem solving.

Then in step 3, students write the process out again, including alternative approaches to the same problem (refer to Figure 6.1).

To go one step further, students can design their own problem.

Suggestions

Use this type of process writing when students need to evaluate how they prepared for a test, began a project, or wrote an examination.

Sample Assignment

Problem: Hydrogen gas and chlorine gas combine to form hydrogen chloride at STP. If 8.9 g of HCl are produced, what volume of hydrogen gas reacted?

Student calculations:

$$8.9 \text{ g} \times 1 \text{ mol}/36.5 \text{ g} = 0.24 \text{ mol HCl}$$

$$H_2 + Cl_2 \rightarrow 2HCl$$

$$1 \text{ mol } H_2 : 2 \text{ mol HCl}$$

$$\frac{0.24 \text{ mol HCl} \times 1 \text{ mol } H_2}{2 \text{ mol HCl}} = 0.12 \text{ mol } H_2$$

$$0.12 \text{ mol} \times 22.4 \text{ L}/1\text{mol} = 2.7 \text{ L } H_2$$

Student notes:

- *I'd better convert 8.9 g to moles because I always have to work in moles.*
- *I can't compare HCl to H_2 until I have a balanced equation.*
- *The gases are diatomic, so they are H_2 and Cl_2.*
- *The balanced equation gives me a mole ratio to multiply by moles of HCl to get moles of H_2.*
- *The reaction is at STP, so I can use molar volume.*
- *If I multiply moles of H_2 by molar volume, I should get litres.*

Figure 6.1: Process notes for a mass-to-volume problem in chemistry

4. Divided Notebook

A Divided Notebook, often referred to as the double-entry or dialectical approach, is a powerful tool. Students increase their depth of understanding by recording information using both

- spontaneous writing (their own words)
- formal note-taking (teacher's words)

How does this improve learning?

The language of formal notes is usually that of the teacher. Students often have difficulty fully understanding these notes. The Divided Notebook allows students to respond to formal notes in their own words, thus making the notes more meaningful.

Procedure

Students divide their notebooks into two sections or divide each page of their notebook into two columns:

Section or Column One—Students keep *standard formal notes* for the science lesson.

Section or Column Two—Students respond *spontaneously* in writing to the formal notes.

In the *spontaneous* writing column, students record

- questions
- predictions
- summaries
- observations
- fleeting associations with personal experiences and other knowledge
- applications
- frustrations

(refer to Figure 6.2)

Divided Notebook: Adapted by permission of the publisher from Connolly, P., & Vilardi, T. (Eds.), *Writing to Learn Mathematics and Science*, (New York: Teachers College Press, © 1989 by Teachers College, Columbia University. All rights reserved.), pp. 51-52, 113-118.

Students can also use these writings to

- record rough data from their laboratory work
- explore a topic further
- review the concepts being learned

Often such writing leads to a proposal or plan for a research project.

Suggestions

During a class lecture, you might want to stop and allow students a few minutes to reflect on the new information and write spontaneously the right column. As students write, the teacher can walk around, and gain a quick and accurate idea of their level of understanding.

Example

Cycles of Matter	
– living things need to grow and to repair	
– they need nutrients (C, H, O, N, etc.) to do this	– *how do nutrients help growth?*
– no new nutrients can enter the biosphere	– *where did they originally come from?*
– nutrients (matter) must be recycled through various matter cycles	– *does our recycling help?*
– these include the nitrogen cycle, the carbon cycle, and the hydrological cycle	– *is that like hydro in Manitoba Hydro?*

Figure 6.2: Divided Notebook entry for an ecology unit.

5. Reading Response Journal

One way to increase students' analytical skills and scientific literacy is to have them read a nonfiction science book and write reflectively about it in a journal.

The added benefits of this strategy are that students realize

- "not all nonfiction books are like textbooks"
- "that they are capable of generating information instead of just regurgitating" (Reynolds and Pickett, 1989, 435-37)

Students are also surprised by their ability to read and understand scientific material.

Procedure

Consider taking the following steps when using the Reading Response Journal:

1. Begin by explaining the assignment requirements and introducing the students to a variety of books.
2. Model what is expected for responses and continue to share student examples all year.
3. Have students write in their journals at least once a week.
4. Expect that the depth of analysis will increase the more they read. Give specific guidelines to help them develop these skills.

Suggestions

As suggested by Reynolds and Pickett (1989), use this as an effective writing-to-learn strategy for all class levels in any science discipline.

Reading Response Journal: Adapted from Reynolds, F. and I. Pickett. "Read! Think! Write!: The Reading Response Journal in the Biology Classroom." *The American Biology Teacher.* Reston, VA: National Association of Biology Teachers, 1989. Used with permission.

Journal Writing Suggestions

This section attempts to answer frequently asked questions about integrating Journal Writing into the science lesson.

How does the teacher introduce Journal Writing? How often are entries made?

With personal response-type writing, the teacher often has to initially make students accountable until students realize the rewards.

- Allow in-class time for spontaneous writing.
- Give students set time limits—three to seven minutes. Insist on no talking during this time.
- Start small. At first, use Journal Writing as an occasional activity.
- Have students try different journal strategies, until they become comfortable with them. A strategy like Divided Notebook takes time to master. Free writing at the beginning or end of every class is a good starting point.

No matter what approach is used, it is important to model the methods and share selected student writing with the class. In this way, students develop the language they need to evaluate new learning in their writing.

How are students taught to write informally?

- For true spontaneous writing, insist that students write without stopping, that is, without taking their pencils off the page. Model this behaviour by writing at the same time.
- Prompt students by asking them to put into words, as specifically as they can, what they are thinking, wondering, and realizing about a lesson.
- Encourage students to examine a concept from several different angles.
- For beginning free writers, ask them write for five minutes non-stop expressing whatever ideas come to mind.

What do student journals look like?

Students can keep their informal writings in a logbook that is handed in periodically. Or, have students keep their notes and reflective writings together in a binder. Log entries or tables of contents could be included to list what is done in class.

How can journal writing help teaching?

When lesson responses are directed to the teacher, containing students' questions/notes about areas of confusion and other valuable information, the teacher can try having a few students go through them and list all the questions for the class. Then, the class can together proceed to find the answers and fill in these gaps in knowledge.

Does the teacher evaluate them?

Teachers should not try to grade or even read every entry—they don't have time! Alternatively, teachers can

- have peers read partners' work
- ask selected students to share their work with the class
- find some interesting entries and display them on the overhead (often this prompts students to get involved)
- have students incorporate self-selected entries in their portfolios

If journals are to count for something, ask students to keep their reflective writing in a separate section or notebook to be turned in periodically. Read and comment on interesting items, and assign a holistic mark based on quantity and quality (refer to Figure 6.3).

Regardless of class size, informal journal writing need not take more teacher time; journals can be spot checked, skimmed, read thoroughly, or not read at all, depending on the teacher's interest and purpose (Fulwiler, 1987b, 15).

Journal Evaluation

Name ________________ Course ______________

Evaluation Period ____________________

Quantity

Number of entries required _____ Number of entries made ______

Score _____

Quality

	Poor					Excellent	Weight
1. Follows guidelines.	0	1	2	3	4	5	x 1 = ___
2. Varies responses using different free writing techniques, process writing, and divided notebook.	0	1	2	3	4	5	x 2 = ___
3. Relates material to own experiences or expresses opinion of content.	0	1	2	3	4	5	x 1 = ___
4. Responds to material other than lecture, such as films, readings, use of small groups, etc.	0	1	2	3	4	5	x 1 = ___
5. Responds critically and reflectively, showing growth in entries and increased understanding of content.	0	1	2	3	4	5	x 2 = ___

Comments:

Score _____
25

Figure 6.3: Sample evaluation sheet for journal entries

Journal Evaluation: Used with permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

The Science Portfolio

A Science Portfolio is a showcase of student work.

Once students develop their writing skills using science journal strategies, they can begin to create more polished works using portfolio strategies. A Science Portfolio is a showcase of student work. Portfolios are increasing in popularity because they allow students to express themselves through an array of communication processes. For example, students might examine a scientific concept by

- using art, poetry, video, music, or multimedia
- designing a problem-solving situation or experiment
- writing about scientific current events or themes (Martin, Miller and Delgado, 1995, 52)

Teachers usually decide on the number and the focus of pieces in a portfolio but students select their best work to be included in the portfolio. A variety of writing-to-learn assignments should be included in every student's Science Portfolio. These might include

- specific journal entries
- student's writings
- best homework assignments
- a writing sample that needs improvement
- explanations of portfolio items chosen
- microthemes

Portfolio Strategies

6. Microthemes

Microthemes are writing assignments designed to help students learn the material by looking at it in a different way (Martin, 1989). This strategy requires more than simply reading the text and memorizing notes. The writer must address specific question(s) to illustrate his/her understanding.

Many universities are introducing Microthemes into their coursework.

Guidelines

- Each Microtheme should be one to two typewritten pages long.
- Students are expected to write in essay format.
- The teacher marks spelling and grammar.
- Adding diagrams is helpful.
- Teachers return work if it is simply rewritten from the text with little or no paraphrasing or if students attain a score of less than 70 per cent.
- Satisfactory work should show an original approach and an accurate presentation of scientific facts.

Sample Microtheme Assignments (Biology)

- Sally is at the back of the room, talking to her tulips as she waters them. You ask her why she would bother wasting her time chatting to her plants. Sally replies that plants are not dumb. Plants show predictable behaviours when exposed to certain environmental conditions, for example, bending towards the light. You ask her what those behaviours are and how plants control their growth, development, and environments. What does she answer?

Microthemes: Adapted by permission of the publisher from Connolly, P., & Vilardi, T. (Eds.), *Writing to Learn Mathematics and Science*, (New York: Teachers College Press, © 1989 by Teachers College, Columbia University. All rights reserved.), pp. 51-52, 113-118.

- When you walked into Grandma's house yesterday, the scent of potted geraniums was overpowering. Grandma was busy planting geranium cuttings so that she would have lots of plants for her flower boxes this spring. As you've been studying about plants in biology class, you confidently tell her that she is helping the plants propagate vegetatively. "What's that?" she asks. Explain vegetative propagation to Grandma. Be sure to include lots of examples (especially those that Grandma would see in her own garden or yard) and to compare vegetative propagation to and contrast it with sexual propagation in plants.

Suggestions

Assign Microthemes for mini-units or concepts that never seem to be covered because of lack of time. Make sure that the concepts can be understood with a minimum of instruction. These might be extensions to units. For example, students can

- study particular elements when the class is examining the periodic table
- research the contributions of particular scientists

Sample Evaluation Scheme

	Poor Excellent	Weight
Follows guidelines	0 1 2 3 4 5	x 3 =___
Uses correct spelling and grammar	0 1 2 3 4 5	x 3 =___
Provides descriptive and relevant examples or visuals	0 1 2 3 4 5	x 3 =___
Expresses main and supporting ideas clearly and logically	0 1 2 3 4 5	x 4 =___
Presents an original approach	0 1 2 3 4 5	x 3 =___
States scientific facts accurately	0 1 2 3 4 5	x 4 =___
Total		100

Other Portfolio Activities

Students may want to add the following or other writing assignments or speaking/listening/viewing activities to their portfolios.

- Students adopt a different role.
- Students address an audience other than the teacher.
- Students use a format different from the traditional science report or Microtheme approach.

In all cases, students are being asked to write about something they are being taught in science—about a particular scientific process, concept, phenomenon, principle, force, etc.

Sample Assignments

NOTE: In the following sample assignments, the word "elements" refers to the elements of the periodic table.

- Make up a story about someone whose life was strongly affected by a particular element.
- Choose a particular element and tell the story of this element since it first existed, as if you were telling it to a six-year-old.
- Tell the story of an element in a "rap" song for a 12-year-old.
- As the element, tell a part of your own story that no human has yet discovered.
- Make up a love story in which the element is a central character.
- Write a mystery story where this element is part of the key to the solution (e.g., The Foul Case of the Acid Bath Murder).
- Develop a myth explaining how this element came to exist (as introduction to the unit).
- Tell a science fiction or fantasy story in a world where this element would be used in ways thought impossible today.
- Make up a case study based on a problem that the element is creating. Examples:
  - Aluminum and Alzheimer's disease
  - Debate about adding fluoride to drinking water
  - Mercury in the fish in Northern Ontario
  - Mercury amalgam in teeth

The teacher may need to remind students that since a case study describes a specific real-life issue, they should include the opposing views that people might have on the topic.

Once students develop their case studies, teachers may want to select the most interesting ones and either assign them to small groups to expand on the previous work or to compare and debate possible solutions. If so, the teacher should ask the students to give enough background and detail, including brief portraits of the key players involved and their points of view.

- Make up a "fractured fairy tale" by adapting an old tale and using scientific information they have learned.
- Imagine you are a particular phenomenon or thing (a chromosome in a 40-year-old female, the heart of a dog, a rock from the Paleozoic era, a neutron in a nuclear weapon, etc.) and tell your story. Use words or pictures or both. Create a play, story, collage, storyboard, comic strip, or photo-essay.
- Tell the story of what happened during a real lab experiment—but change the ending if you like (narrating the discovery process).
- Relate in writing an anecdote from personal experience that illustrates the science principles/skills being learned.
- Create a graphic model to represent new learning (e.g., three phases of matter).
- Create a cartoon to humorously personify an organism being studied. Use professional examples like Gary Larson's *The Far Side* as models.
- Analyse the influence of the media on people's understanding of science issues or generalize about the prominence of certain science issues in the media at certain times.
- Analyse a government position on a particular issue affecting the economy, human health, technology, or the environment. Account for factors like fiscal restraint, rights of various stakeholders, and political considerations.
- Create a storyboard for a film that shows a process or explains a concept for a particular audience.

- Analyse and compare newspaper editorials on certain science issues—examine and evaluate authors' views, accuracy of information presented, simplification of information for lay audience, etc.
- Dramatize a scientific concept or process and present it to elementary or junior high students.
- Analyse the treatment of a science-technology-society-environment issue in a feature film, noting how its presentation, accuracy, and viewpoint were presented.
- Analyse the image of science and scientists in the media.
- Research and analyse the construction of special effects for feature films. Students might use helpful publications such as *Cinefex* (a periodical available quarterly from Valley Printers, P.O. Box 20027, Riverside, California 92516).
- Debate the scientific use of animals for product testing.
- Evaluate and compare "environmentally friendly" products or analyse advertisements for such products.
- Record the process of a complex experiment by taking colour photos or slides. Arrange and present these as a photo essay or documentary.
- Analyse advertisements which make claims about a particular product and design experiments to test the claims.

Samples of Students' Work (Portfolio Writing)

Assignment for Chemistry

You have just been introduced to the mole concept. This is a relatively abstract concept as it is rather difficult to picture 6.02×10^{23} of anything! Explore this topic through creative writing by choosing one of the following tasks. You have 30 minutes to complete the task.

- As a mole, write a job advertisement for replacement particles (you need to keep up your numbers as some particles have gone out on strike).
- Write a poem about "Marvin the Mole" (see sample).
- As an atom, picture yourself at the bottom of a great mountain of atoms (a mole's worth). Write a letter home describing your situation.

Student Response

Marvin the Mole

Marvin the Mole was a jolly good soul,
And a jolly good soul was he.
He called for his pipe and he called for his bowl,
and he called for his fiddlers 6.02×10^{23}

Marvin the Mole, the jolly good soul, went uptown, to shop for the day.
He went to the store and got a mole of eggs, but didn't have money to pay.
So Marvin the Mole stole the eggs, which doesn't seem right to me!
And he realized the eggs would cover the world, as far as he could see.

Marvin's realization of this slight problem made him think a bit.
"Hey!" he thought with a slight smile, "If I crack the eggs, they'll fit!"
Marvin figured that if he did this, he would be one of the town's heroes.
So of the eggs, he cracked 602, followed by 21 zeros.

Marvin the Mole liked counting with moles, like every good Chemist would.
He knew that the mass of one mole of a substance is determined
by using a periodic table, like every good Chemist should.
Marvin the Mole went back to his hole, with his billions of baby chickens.
He ate half a mole, put the rest in a bowl, and died of eating too many,
because they were finger lickin".

Sample Evaluation Scheme

Followed guidelines	- 4/4
Chemistry content	- 6/8
Clarity and Logic	- 3/3
Creativity	- 3/3
Polish	- 2/2
Total	18/20

Assignment for Biology

- Write a lyric poem on any topic in biology. Focus on an organ, an organ system, or the interaction of two systems.
- Use a minimum of 16 lines, either 4_, 6_ or 8_ line stanzas possible.
- Choose a rhyming scheme. i.e., AB AB ABBA

Student Response

A Biological Rhyme

Biology is a class where we learn about our body
From the cells of life to the human anatomy
From the parts of our eyes, to the marrow of our bones
How muscles behave in achieving good muscle tone.

The excretory system was very enlightening
but when I saw certain parts, I found them quite frightening
Dissection is cool, cutting organs is great, but touching and
handling them is something I hate.

The digestive system takes in foods that we eat,
And even has something for us to excrete,
Blood, corpuscles, neurons and capillaries,
words which broaden and enhance my vocabulary.

Inside my brain this course merrily flows,
with thoughts of Biochemistry or H_20,
Some words can't be found in an ordinary dictionary,
so I look in my text under a word called "Glossary."

Exams and tests are not a big thrill,
So usually before them my body feels ill,
I'll be very simple and yet quite discrete,
Biology is interesting and really quite neat.

From parts of the cell to the biological laws,
It's time for me to stop writing and hold all applause!

Sample Evaluation Scheme

English/Rhyme	- 3/3
Length	- 1/2
Clarity	- 2/2
Biology content	- 4/4
Creativity	- 9/9
Total	19/20

Summary

Using writing-to-learn strategies will stretch students' minds and help them learn. Students will begin to relate what they have been taught to what they already know; to use that information creatively and to assess how well they have learned it. The depth of analysis and kinds of skills shown by the students will depend on the type of product: journals or portfolios.

"Journal writing won't make passive students miraculously active learners; it does, however, make it harder for students to remain passive" (Fulwiler, 1987b, 15).

Journals contain more informal, reflective writing. The types of entries can be quite simple or very structured and can vary in depth and frequency. "Journal writing won't make passive students miraculously active learners; it does, however, make it harder for students to remain passive" (Fulwiler, 1987b, 15).

Teachers are encouraged to introduce writing-to-learn opportunities in their classes. This type of writing "deserves serious reconsideration, increased attention, and ever more thoughtful practice—across the whole school curriculum" (Fulwiler, 1987b, 10).

References

Berenson, S., and G. Carter. "Changing Assessment Practices in Science and Mathematics." *School Science and Mathematics* 95.4 (1995): 182-186.

Botstein, L. "Forward: The Ordinary Experience of Writing." Eds. P. Connolly and T. Vilardi. *Writing to Learn Mathematics and Science*. New York, NY: Teachers College Press, 1989. xi-xviii.

Connolly, P. "Writing and the Ecology of Learning." *Writing to Learn Mathematics and Science*. Eds. P. Connolly, and T. Vilardi, New York, NY: Teachers College Press, 1989. 1-14.

Fulwiler, T. *The Journal Book*. Portsmouth, NH: Heinemann, 1987a.

_ _ _. *Teaching With Writing*. Portsmouth, NH: Heinemann, 1987b.

Fusco, E., and G. Fountain. "Reflective Teacher, Reflective Learner." *If Minds Matter: A Foreword to the Future*. Vol. 1. Eds. A. Costa, J. Bellanca, and R. Fogarty. Palatine, IL: Skylight, 1992. 239-255.

Kenyon, R. "Writing is Problem Solving." *Writing to Learn Mathematics and Science*. Eds. P. Connolly, and T. Vilardi. New York, NY: Teachers College Press, 1989. 73-87.

Martin, K. "Writing 'Microthemes' to Learn Human Biology." *Writing to Learn Mathematics and Science*. Eds. P. Connolly, and T. Vilardi. New York, NY: Teachers College Press, 1989. 113-118.

Martin, M., G. Miller, and J. Delgado. "Portfolio Performance." *The Science Teacher* 62.1 (1995): 50-54.

Reynolds, F., and I. Pickett. "Read! Think! Write!: The Reading Response Journal in the Biology Classroom." *The American Biology Teacher* 51.7 (1989): 435-437.

CHAPTER 7: TECHNICAL WRITING IN SCIENCE

CHAPTER 7: TECHNICAL WRITING IN SCIENCE

Science teachers must teach the fundamentals of technical writing because our students will require these technical writing skills for a variety of professional and non-professional purposes (e.g., resumes, correspondence, reports).

"Technical writing conveys specific information about a technical subject to a specific audience for a specific purpose" (Markel and Holmes, 1994, 2). Engineers, scientists, and business and other technically trained people find that they spend one-fifth of their time writing such technical documents, with the percentage increasing as they advance in their fields.

Technical writing skills are now considered to be an essential component of science education, so students now learn how to write technical reports, research papers, proposals, and laboratory and scientific reports.

This chapter describes the characteristics of technical information, the ethics of writing, guidelines for writing, and technical writing formats.

Characteristics of Technical Information

Technical information should be

Clear Technical information should be stated simply, without unnecessary jargon or large words so it is easier to read.

Concise Technical information should be written with a minimum number of words, yet without losing clarity, meaning, or fluency.

Correct All technical documents must observe the conventions of grammar and punctuation.

Accurate Information such as data, procedures, and materials must be stated without error.

Comprehensive Manuals or documents should contain all the information a reader might want to complete a task or fix a problem. This may include, for example, all necessary phone numbers, addresses, or a troubleshooting section.

Accessible What sets a technical document apart from a novel is that all information can easily be found. The reader should not have to search excessively to complete a task. This can involve, among other items, organizing the information, having a complete index, and using different kinds of layout and design techniques.

The Ethics of Writing

While technical information should contain the above characteristics, it should also meet certain ethical standards. A number of ethical issues face all technical writers. Perhaps the two most common issues addressed in our science classes are plagiarism and the altering of experimental data. Ethical standards apply to writers in business and industry as well. Compound these standards with obligations to the employer, having documents with several writers, and the need to protect trade secrets, and the situation can become very complex!

Expectations must be made clear. Most companies have formal codes of conduct for their technical reports. Science teachers must take the same approach—they must clarify what they expect and what they will accept regarding ethical writing in their classrooms.

Guidelines for Writing

Each technical writing textbook will have its own approach to writing. As well, each student will bring to class his/her experiences with the writing process. Consult both textbooks and students before beginning instruction on a particular technical writing approach.

Regardless of the format, writing follows four basic phases:

1. pre-writing
2. writing the first draft
3. revising
4. preparing the final draft (Sebranek, Meyer, and Kemper, 1996)

Students should be familiar with these phases as they closely follow the writing process taught in other courses.

A similar approach was developed by an Australian school system to help students prepare for science examinations. This approach is explained below. This system benefitted students in two ways. Students

- developed their writing skills
- learned about science using this writing process (Havel, 1995)

Students will not instantly acquire the skills, so they will have to practise them each time they approach a new writing assignment. Teachers can guide students through each of the phases as outlined below.

1. Pre-Writing Phases

Before students get started with their writing, the teacher should ask the students to

a. *choose a topic that interests them*

   By picking what they want to write about, they are more motivated to write (Havel, 1995).

b. *read up on the topic and identify what they really want to know about the subject*

   At this time, students should demonstrate the relationship of their research topic to the current topic of study by means of a Concept Map (Havel, 1995, 331). (The Concept Map strategy is reviewed in *Chapter 4: Developing Scientific Concepts Using Graphic Displays.*)

c. *articulate a focus or thesis statement after examining the topic*

   This statement would be only one or two sentences and express what the student plans to research. Another option is for them to state the focus as a set of research questions, such as, "What environmental conditions have endangered burrowing owls?" "What must be done to reverse this?" Identifying three or four research questions makes the task of collecting information easier. These questions should be reviewed by the teacher before research begins to make sure they are neither too broad nor too narrow in focus.

d. *collect information about their research questions*

Collecting information requires specific skills many students do not have. To do research, teachers must monitor their students to see whether they know how to

- distinguish among different resources
- find resources
- use an index
- read critically
- put the information in point form

Students can develop better research skills if these skills are modelled. For example, students can learn how to follow a Research Notes Frame, to record research information (refer to Figure 7.1). For a blank Research Notes Frame, refer to Attachment 7.1 at the end of this chapter. References such as dictionaries, general encyclopedias, specialized encyclopedias, factual books, or computer resources can all be accessed. For each entry, have students

- name the type of resource
- identify all source information about the resource being referenced
- paraphrase the answer to their research questions

If students cannot find new or relevant information, they should note that as well. Perhaps their research questions need revising.

Research note-taking skills can always be taught in more depth. Students need to learn the differences between

- summarizing
- paraphrasing
- quoting

Clearly distinguishing among these skills early in the note-taking stage prevents confusion later when students are writing their first drafts.

RESEARCH NOTES Page ____

Topic: Organ Donation (OD)

Research Questions:

1. What science supports OD?
2. What technology is needed for OD?
3. What issues are raised by OD?
4. What is society's viewpoint about OD?

Resource Type: newspaper article

Reference: Anderson, P. "Confusion Over Legal Death May Hamper Organ Harvesting." *The Ottawa Tribune*. 9. June. 1993: A3.

Answers to Questions:

1. - confusion about when someone is "brain-dead"
2. - technology only works within a strict time frame
3. - when is someone dead? (ethically)
   - creates hesitance and reluctance to consult patients' families.
4. - when is someone dead? (legally)
   - there is little consistency of opinion among doctors as to signs of brain death

Figure 7.1: Sample research notes

Experimental data is another key source of information. Students must learn to take accurate and complete notes during their experiments. By using a Laboratory Report Outline, students can record their data and information as the laboratory proceeds (refer to Attachment 4.4 for a blank form of this outline).

e. design a writing plan

After students collect information, they must design a writing plan. This includes

- writing an outline
- searching for additional information
- revising the outline as they uncover new information (Sebranek, Meyer, and Kemper, 1996)

Research Notes Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

2. Writing the First Draft

Once students have collected sufficient information and written and revised their outline, they can begin to write their first draft. To do this, students should

- identify and focus on the audience (Who are they? What is their knowledge base?)
- prepare the introduction, stating the purpose and scope
- follow with the discussion or body of the paper, considering the format (see page 7.9)
- finish with the conclusions
- add the remaining sections later (e.g., references, appendices)

The initial writing is often difficult for many students. To get over their writer's block, students, Blicq suggests, should skip the first few statements and start by writing the second or third paragraph (1992). He also indicates students need to work in a quiet place, where continuity of thought is possible. Students might find the classroom too distracting, making it difficult to do much more than outline their paper in this setting.

3. Revising

Writing is recursive in nature, as it involves editing and revising an original draft many times. During revision, students should

- *Presentation*
  - follow an appropriate format (e.g., letter, laboratory report, research paper)
  - include necessary components of the chosen format (refer to Figures 7.2, 7.3, and 7.4)
- *Organization*
  - focus on the central idea
  - place main ideas prominently (e.g., topic sentence for each paragraph)
  - present ideas logically with supporting information (e.g., clear relationship between topic sentence and paragraph content)
  - use visual organizers such as headings where appropriate
  - provide clear transitions between ideas

- *Sentence Structure*
  - use correct grammar and punctuation
  - write clear, concise sentences
- *Word Choice*
  - economize on words (e.g., use *although* rather than *despite the fact that*)
  - introduce strong, descriptive verbs
  - avoid repetition (e.g., *complete stop*)

4. Preparing the Final Draft

In the final stages, students will need to

- prepare the text of the document
- organize and compile the sections
- number the pages
- proofread the entire document

These four writing phases can be applied to many formats as outlined below.

Technical Writing Formats

Scientists use a number of writing formats, including letters, field trip reports, project status and completion reports, inspection reports, laboratory reports, technical proposals, resumes, and scientific papers. The most common formats employed in the science class are research papers, laboratory reports, and scientific papers. These formats are described below.

Students have the right to expect that the technical writing skills acquired in their science courses are similar and transferrable from one class to another. Likewise, these skills are important in the world beyond school.

Research Paper

A research paper is a carefully planned essay that has been thoroughly investigated and analysed by the writer. Research papers are written to share new information or to argue a point. What sets them apart from other essays is the amount of information gathered and used in the writing. A research paper may include ideas from books, magazines, newspapers, computer files, or interviews (Sebranek, Meyer and Kemper, 1996, 163).

Figure 7.2 offers a guideline for writing a research paper.

Research Paper Format	
Cover	- includes title and name of author (informative title choice) - jacket conveys professional image
Title Page	- includes title, name of author, and date - notes intended audience
Summary	- summarizes the entire report including purpose - uses non-technical language
Table of Contents	- lists contents in order - includes appendices
Introduction	- indicates purpose and scope of report - provides background
Discussion	- discusses main ideas and supporting details (body of paper) - properly referenced all material
Conclusions	- summarizes the major conclusions of the discussion
Recommendations	- states specific action, if warranted
References	- lists sources using a particular method
Appendice(s)	- includes supporting data, charts, tables, and figures (some papers include these in the discussion)

Figure 7.2: Main components of a research paper (**Note:** Sections can be omitted or rearranged.)

Laboratory Report

Laboratory reports may be "written in industry to document laboratory research or tests on materials and equipment" or "written in academic institutions to record laboratory tests performed by students" (Blicq, 1992, 93). The purpose of the lab and the laboratory report is to help students make connections between what they saw, experienced, or discovered and the scientific understanding that explains the phenomenon under investigation. (A suggested format for laboratory reports is outlined in Figure 7.3.)

Readers of academic laboratory reports are usually professors and instructors. They want thoroughly documented details so they can easily assess how well the student understood the subject and the experimental results (Blicq, 1992, 93).

If students filled in a Laboratory Report Outline as they conducted the experiment, they could see an overview of their work before beginning their formal writing. This frame follows the same format as the formal laboratory report. (See an explanation of the laboratory report outline and an example in *Chapter 4: Developing Scientific Concepts Using Graphic Displays.*)

Scientific Paper

A scientific paper either identifies and attempts to resolve a scientific problem or tests (validates) a scientific theory. It accomplishes this by describing the four main stages of research, which are to

- identify the problem or theory
- set up and perform tests
- compile test results into tables (findings)
- analyse and interpret findings (Blicq, 1992, 224)

The first time many students become aware of scientific papers is when they are asked to do some research for their university or college papers. When they start reading a scientific journal, they recognize how similar the format is to a laboratory report. They also come to realize that reading abstracts allows them to prescreen articles for relevancy, helping them research more efficiently.

Students can become familiar with scientific papers before leaving high school by reading and writing them. For example, long-term laboratories, such as the genetic research performed with fruit flies in biology, could be written in scientific paper format. A suggested scientific paper format is outlined in Figure 7.4.

Laboratory Report Format

Experiment #	Laboratory Title	Name

Introduction	- purpose (Why is the laboratory being done?) - hypothesis and rationale (What do you think will be found and why?) - brief background on the subject
Experiment	- materials/apparatus (Make a concise list.) - methods/procedure (Write an exact account.) (An option is to refer to the laboratory manual and clearly list any changes.)
Results, Data, or Observations	- general observations - data tables (Follow a prescribed format.) - graphs and calculations (These could be in the Analysis section, if interpretive.)
Analysis or Discussion	- analysis (interpret results by providing evidence.) - integration of the theoretical with experimental (Was hypothesis proven correct? What are the implications?) - error analysis
Conclusion	- summary (Briefly summarize discussion indicating if objectives were met.)

Figure 7.3: Laboratory report format for short-term laboratories

Scientific Paper Format	
Title and Author	- title is specific and clear - author(s) and affiliation are listed underneath
Abstract	- summarizes paper and emphasizes results - captures reader's interest - length is 100-250 words; brief is best
Introduction	- outlines purpose of experiment and defines problem or theory tested - gives background information by reviewing pertinent information - briefly describes approach taken - concludes with statement that outlines findings
Materials and Methods	- describes how tests were performed - is written in detail so experiments can be easily repeated
Results	- states findings - includes tables, charts, and graphs
Discussion	- analyzes and interprets findings - compares results to theoretical expectations - examines trends and correlations - discusses sources of error - draws conclusions
References	- lists sources of information consulted

Figure 7.4: Scientific paper format for long-term laboratories

Summary

While technical communication, including technical writing, is an integral element in the English Language Arts curriculum, this type of writing is being taught in many subject areas. Science and language arts teachers can coordinate efforts in teaching the characteristics, ethics, and methods of technical writing, with science teachers concentrating on a specific format, such as laboratory reports.

However, maintaining consistency across science courses and other disciplines is important. By using guidelines for research papers, laboratory reports, and scientific reports, teachers can present consistent approaches to technical writing that will help students write better on tests and assignments and in the workforce.

The ability to write well is a skill that has market value. As stated by Markel and Holmes, "the technical person's value to the company will depend more and more on the quality of writing" (Markel and Holmes, 1994, 3).

"However, … writing skills do not develop unless teachers are willing to invest the time and … provide the opportunities for the students to engage in the total writing process" (Havel, 1995, 334). Students writing in our science classes today will be the technical writers of the future.

References

Blicq, R. *Technically-Write!: Communicating in a Technological Era.* 4th Canadian ed. Scarborough, ON: Prentice-Hall Canada, 1992.

Havel, P.D. "Assignments: An Important Means of Learning Subject Matter and the Writing Process." *The American Biology Teacher*, 57.6 (1995): 330-334.

Markel, M. and H. Holmes. *Technical Writing: Situations and Strategies.* 1st Canadian ed. Scarborough, ON: Nelson Canada, 1994.

Munter, Mary. *Business Communication: Strategy and Skill.* Englewood Cliffs, NJ: Prentice-Hall, 1987.

Sebranek, P., V. Meyer, and D. Kemper. *Writers INC: A Student Handbook for Writing and Learning*. Toronto, ON: D.C. Heath Canada, 1996.

Attachment 7.1

RESEARCH NOTES Page ____

Topic: ______________________

Research Questions:

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

Resource Type: ______________________

Reference: ____

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Answers to Questions:

1. ____

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2. ____

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3. ____

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4. ____

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